SOCIAL-COMPARATIVE FEEDBACK AND LEARNING

THE EFFECTS OF SOCIAL-COMPARATIVE FEEDBACK DURING MOTOR SKILL ACQUISITION IN HIGHLY-MOTIVATED LEARNERS: APPLICATIONS TO MEDICAL EDUCATION

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LAY ABSTRACT

This dissertation includes three original studies designed to examine the effects of social-comparative feedback during skill acquisition in highly-motivated learners (e.g., medical trainees). Regardless of actual task performance, novice medical trainees who were provided with feedback during the learning process indicating that they were performing worse than the group average, experienced significant detriments to their psychological and behavioural outcomes. This effect was present regardless of the task being learned (i.e., key-pressing or suturing) or who was delivering the feedback (i.e., a hypothetical 'expert' or 'peer'). Receiving better-than-average feedback did not result in any additional psychological and behavioural benefits. Contrary to the research with non-medical students, where "you are above-average" social-comparative feedback facilitates learning and "you are below-average" social-comparative feedback is no different than a control condition, these studies suggest that the *experience* of receiving below-average feedback during the learning process can be detrimental for highly-motivated novice learners. These findings are important to consider in both the context of feedback delivery and remediation as they provide evidence that novice medical trainees, regardless of the task and feedback provider, experience difficulty in receiving information that they are performing relatively poorly compared to their peers.

ABSTRACT

Social-comparative feedback (i.e., providing a learner with information regarding his/her performance relative to a group average) has been shown to influence a learner's psychological and behavioural outcomes during motor skill acquisition (Avila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay, Lewthwaite, & Wulf, 2012; Stoate, Wulf, & Lewthwaite, 2012; Wulf, Chiviacowsky, & Cardozo, 2014; Wulf, Chiviacowsky, & Lewthwaite, 2010, 2012; Wulf & Lewthwaite, 2016). This research indicates that motor skill acquisition is facilitated when learners believe they are performing better than the average, regardless of their actual performance. It has been suggested (Wulf & Lewthwaite, 2016) that a better-than-average mindset enhances psychological factors such as self-efficacy and motivation and in turn, actual behaviour. However, there is also evidence to suggest that self-efficacy (having state-like properties) and motivation (having both state and trait-like properties) are related in terms of their affective influence on learning (Bandura, 1997; Schunk, 1990, 1991, 1995) but the relationship between the two constructs and its subsequent outcomes remain unclear. Even though individual differences in motivation have been suggested to influence self-efficacy beliefs, they have been largely ignored in this line of research. There is also evidence to suggest that learners possessing high levels of motivation (whether that may be at a trait or state level) may not interpret feedback in the same manner (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-

Jones, 2002; Harmon-Jones, Harmon-Jones, Fearn, Sigelman, & Johnson, 2008; Harmon-Jones & Mills, 1999; Harmon-Jones, Schmeichel, Inzlicht, & Harmon-Jones, 2011; Steele, 1988). Therefore, the goal of this dissertation is use both theoretical and applied perspectives to examine the degree to which social-comparative feedback affects psychological and behavioural outcomes in highly-motivated learners (e.g., medical trainees) learning procedural skills.

Independent of actual performance, we provided manipulated feedback information to novice pre-clerkship medical trainees while they were learning motor skills to suggest that they were performing better or worse than the average. The first study used a basic sequential key-press learning task (Eliasz, 2012) and a basic suturing task to explore the role of social-comparative feedback in medical trainees and tested whether features of the task were important (i.e., basic laboratory task or technical skill task) during the interpretation of this feedback. The second study used the same experimental paradigm to extend our results to a relevant medical education context (i.e., medical trainees learning basic suturing techniques). The final study examined whether the credibility of the feedback provider (i.e., expert versus peer) played a role in how social-comparative feedback was being internalized by novice medical trainees.

Our initial study demonstrated that, compared to those receiving positive or no social-comparative feedback, medical trainees receiving negative social-comparative feedback during motor skill acquisition had significant difficulties in learning both the laboratory and technical skill task. These findings suggested that

compared to other learners, novice medical trainees (a subset of highly-motivated learners), responded differently to social-comparative feedback. The second study replicated this pattern and revealed that medical trainees receiving below-average feedback during technical skill acquisition experienced significant detriments to their performance, learning and self-efficacy. Our final study found that regardless of the feedback source (hypothetical expert versus another peer), the *experience* of receiving negative social-comparative feedback impacted self-reported psychological measures and the immediate performance of a basic surgical technique.

This dissertation provides, to the best of our knowledge, the first demonstration that medical trainees, a subset of highly-motivated learners, interpret social-comparative feedback differently than other learners studied in the literature. More specifically, receiving positive social-comparative feedback did not facilitate the learning process as found in previous studies with non-medical learners, while the delivery of negative social-comparative feedback, irrespective of task or feedback provider, was psychologically and behaviourally detrimental to novice medical trainees learning motor skills.

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The greatest gift you can give someone is your time because when you give your time, you are giving a portion of your life that you will never get back.
~Anonymous

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DEDICATION

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AUTHOR CONTRIBUTIONS

This dissertation contains five chapters of original research conducted by the author except for the contributions made by the dissertation supervisor, Dr. James Lyons and the specified contributions of the co-authors.

As primary author, I solely prepared this dissertation document and was significantly involved in all aspects of the research process including idea conceptualization, study design, ethics application writing and submission, data collection, data processing and analysis, and manuscript preparation.

Dr. James Lyons provided mentorship throughout all phases of this work and contributed to the study conception and design, resources for data collection, interpretation of the results, and the editing of this dissertation document. Dr. Nicole Woods contributed to the study design (Chapters 2 and 4), data analysis, and manuscript preparation for Chapters 2, 3 and 4. She also provided mentorship throughout the progression of the dissertation and arranged laboratory space for data collection (Chapters 2 and 4). Dr. Adam Dubrowski provided theoretical and applied mentorship during the phases of this dissertation, contributed to data collection resources for Chapter 3 (laboratory space and equipment requirements) and contributed to the study design, data analysis, and manuscript preparation for Chapters 2, 3 and 4. Dr. Aaron Knox provided expert content knowledge and modeled all of the suturing techniques for the training videos used in Chapters 2, 3, and 4. He also contributed to the study design and the scoring of trainee performance (blinded) on clinical measures in Chapter 3. Dr. Faizal Haji contributed to the study design and the scoring of trainee performance (blinded) on clinical measures in Chapter 3. David Rojas contributed to the study design in Chapter 3 and the filming and production of the training videos used in Chapters 2, 3, and 4. Zain Khan contributed to the development and modification of the online platform (OPEN) that was used to both display feedback and collect the measures outlined in Chapter 4. Dr. Bill Kapralos contributed to data collection resources (OPEN) outlined in Chapter 4.

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LIST OF ABBREVIATIONS

ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
CS	Corner Stitch (half-buried horizontal mattress) suturing technique
CL	Checklist (suturing)
e.g.	for example
GRS	Global Rating Scale (suturing)
HM	Horizontal Mattress suturing technique
ICC	Intraclass correlation
ICSAD	Imperial College Surgical Assessment Device
i.e.	that is
KP	Knowledge of performance
KR	Knowledge of results
M	Mean
ms	Millisecond (unit of time)
MT	Movement time
NASA-TLX	National Aeronautics and Space Administration-Task Load Index
OPEN	Observational Practice and Educational Networking (online platform)
s	Second (unit of time)
SI	Simple Interrupted suturing technique
SD	Standard deviation
SE	Standard error
SPSS	Statistical Package for the Social Sciences

CHAPTER 1:

GENERAL INTRODUCTION

1.1 – RATIONALE

Feedback provides a window into understanding our performance. Regardless of the information source (i.e., augmented/inherent), it is well accepted that feedback plays an essential role in the performance and learning of motor skills. Beyond its informational role, feedback can motivate task practice (Cimpian, Arce, Markman, & Dweck, 2007; Dweck & Leggett, 1988; Eliasz, 2012; Fishbach, Eyal, & Finkelstein, 2010; Graham & Golan, 1991) or be used as a social tool to provide us with knowledge about how we are performing relative to others (Festinger, 1954; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; McKay et al., 2012; Stoate et al., 2012). Due to the social nature of learning, social comparisons are powerful determinants in modifying our mindsets and motivation, which can in turn modify our own individual actions and even impact how we learn a skill (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2016). However, there is evidence to suggest that how feedback is received and internalized depends not only on social or situational factors but also on various individual factors – one of these being motivation (Aronson, 1992; Campbell & Sedikides, 1999; Festinger, 1957; Frey, 1986; Sedikides, 1993; Shepperd, Malone, & Sweeny, 2008). There is evidence to suggest that learners possessing high levels of motivation may not interpret feedback in the same manner (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988);

however, it is unclear how the interaction between socially-relevant feedback and motivation may influence a *highly-motivated* individual during the motor learning process. Since socially-relevant feedback is common in many learning environments, it is important to understand how these construct interact together during skill acquisition. This dissertation examines the effects of social comparisons (specifically in the form of social-comparative feedback delivery) on motor skill acquisition in medical trainees, which represent a subgroup of highly-motivated learners. Since medicine often creates instructional settings carrying elevated costs of failure, facilitation of skill acquisition for medical learners is an important area in terms of both theory and application.

1.2 – GENERAL CHAPTER OUTLINE

The purpose of this chapter is to provide a critical overview of the literature related to both feedback and learner motivation, and its psychological and behavioural influence on the motor learning process. Following a brief introduction to relevant terminology, this chapter begins by examining feedback from an informational, motivational and social perspective in order to provide a better understanding of how the delivery of feedback modifies a learner's mindset and interpretations. Feedback delivery however, only accounts for half of the feedback conversation; receiving and responding to feedback is just as critical with respect to learning outcomes and is discussed next. The remainder of the chapter exposes how self-efficacy, motivation, and individual differences can further modify feedback interpretation, transform the feedback conversation and ultimately, the learning process. The chapter finishes by outlining the objectives and hypotheses of three studies designed to address the overall goal of the present research program, which is to examine the effects of social-comparative feedback during motor skill acquisition in highly-motivated learners.

1.3 – RELEVANT TERMINOLOGY

1.3.1 – *Augmented Feedback*

Augmented feedback refers to performance information that is provided to the learner from an external source and augments (adds to) the learner's own inherent feedback to provide a more comprehensive understanding of movement performance (Schmidt & Lee, 2011, 2014). Throughout this dissertation document, the term *augmented feedback* will be used interchangeably with the term *feedback*.

1.3.2 – *Social-Comparative Feedback*

The focus of this dissertation is on the effects of a specific type of augmented feedback: social-comparative feedback. Social-comparative feedback is still performance information, however in this case the feedback is situated within a social context. More specifically, social information is presented to learners in the form of a group average, which allows them to make sense of their own performance by comparing themselves (in this case, their performance) with others (Festinger, 1954). In this research program, social-comparative feedback is provided deceptively to learners in order to deceive them into believing that they are performing either better or worse than the group average, regardless of their actual performance. The rationale for providing this feedback deceptively is to ensure that learners received the same comparative information to try and regulate their reactions to social comparisons (in other words, inferences about their own absolute performance standing as a consequence of comparisons to the group average).

1.3.3 – *Motor Skill Acquisition*

The execution of a new movement, and how well that movement is acquired and ultimately learned, can be measured across three general phases of the learning process: acquisition, retention and transfer. The acquisition phase is the initial practice (motor performance) of the new skill. Motor performance is the observed behaviour of a voluntary action, whereas motor learning is defined as a relatively permanent change in an individual's capability to perform a skill and is typically inferred through performance on retention and transfer tests (Schmidt & Lee, 2011, 2014; Schmidt & Wrisberg, 2008). The retention phase, completed after a specified time following the practice phase, is identical for all learners (excludes any experimental manipulation), and tests how much of the skill was retained from the acquisition phase. The generalizability of these internal processes can be inferred through performance on transfer tests. The transfer phase follows the retention phase and is identical for all learners (again, excluding any experimental manipulation), however it measures how well the internal processes that were developed during acquisition can influence the performance of a novel task that the learner was never exposed to ('near' and 'far' transfer imply the degree of similarity to the practiced task) (Schmidt & Lee, 2011, 2014).

Since the purpose of this dissertation is to examine how specific feedback (social-comparative) manipulations influence the learning process, the experiments outlined in this dissertation are designed to provide a comprehensive overview of the effects across three phases of the skill acquisition process. As a result, all three experiments presented in this document measure acquisition performance (performance during practice), retention performance (10 minutes or 24- to 48-hours following practice), and near transfer performance (performance on a novel task that is similar to the practiced task).

1.3.4 – *Mindset*

The social-comparative feedback presented to learners in the three studies of this dissertation is intended to alter the learner's "mindset" prior to and during skill acquisition. For the purposes of this dissertation, a mindset is a collection of beliefs, attitudes and expectations that frames the state of the mind and shape one's interpretation and response to a situation (Gollwitzer, 1990).

1.3.5 – *Self-Efficacy*

The social-comparative feedback presented to learners in the three studies of this dissertation is also intended to modify task-specific self-efficacy beliefs throughout the learning process. Self-efficacy is well-studied in the literature and refers to an individual's belief in his/her ability to do a task-specific behaviour (Bandura, 1986, 1997).

1.3.6 – *Motivation And Highly-Motivated Learners*

Motivation is the determination or drive that one has towards an action, which can sustain behaviour and/or direct thoughts, energy, intentions, and behaviour (Lewthwaite, 1990; Lewthwaite & Wulf, 2012; Ryan & Deci, 2000). Although all learners will have some degree of motivation towards or even away from a task (Lewthwaite, 1990), the level to which a learner is motivated is dependent on the strength or the intensity of the determination. The driving force of an action can be orientated intrinsically (e.g., doing an activity for the pure enjoyment of it) or based on something external to the self (e.g., rewards) (Ryan & Deci, 2000). However, the orientation of one's motivation will most likely not be purely based upon a singular type of motivation (e.g., intrinsic or extrinsic) but rather a combination where the dynamics will depend on the context.

Although task motivation accounts for an important part of goal achievement, individual differences related to motivation can also have a unique influence on how a task will be approached. Specifically, the underlying motivational disposition that a learner has (i.e., trait motives) can also become a significant force that drives action(s) (Heggestad & Kanfer, 2000; Kanfer & Ackerman, 2000; Matthews, Davies, Westerman, & Stammers, 2000). This dissertation specifically examines how social comparisons (namely, social-comparative feedback) affect highly-motivated learners. Since medical trainees represent a subset of highly-motivated learners, the sample will be drawn from this group of learners.

1.4 – FEEDBACK THROUGH AN INFORMATIONAL LENS

In the motor learning domain, the traditional view of feedback has focused on the informational properties that it provides to the learner during and following task performance (Salmoni, Schmidt, & Walter, 1984). Beyond inherent feedback (i.e., sensory feedback such as proprioception that is intrinsic to the learner), learners are often also exposed to extrinsic sources of performance-based feedback (i.e., an instructor). This type of external feedback augments (adds to) the learner's own inherent feedback and provides a more comprehensive understanding of his/her performance (Schmidt & Lee, 2011, 2014). Augmented feedback is particularly valuable if a learner does not have enough information and/or cannot interpret his/her intrinsic feedback that is necessary for effective skill acquisition (e.g., error-detection and -correction processes). Providing the learner with augmented task-relevant feedback supports the learning process and the development of skill expertise. For example, to advance an athlete's skill acquisition of a soccer kick, a coach may choose to describe how the athlete is performing the kick and/or prescribe potential solutions for skill improvement. However, the type, amount and timing of augmented feedback that is optimal for successful performance and learning will depend on both the skill level of the learner and the complexity of the task (Schmidt & Wrisberg, 2008; Wrisberg, 2007).

Augmented feedback can be delivered to the learner in the form of *knowledge of results* or *knowledge of performance*. Knowledge of results (KR) provides the learner with response-produced information about a movement outcome (e.g., the success of meeting the task goal). In contrast, augmented feedback that is focused on the quality of the learner's movement is termed knowledge of performance (KP) (Salmoni et al., 1984; Swinnen, 1996). In a common laboratory key-pressing sequence task, a learner may be given the task to perform a sequence in a specified amount of time (e.g., 10 s). If the learner's performance is unsuccessful, the experimenter may then provide the learner with additional information about the movement such as, 'your movement time was 13 s' (KR), or 'you pressed the second key in the sequence too slowly' (KP). Both KR and KP feedback in this example provide the learner with actual performance information relative to the task goal that was not satisfied (i.e., performing the sequence in 10 s). However, the most favourable type of feedback will depend on the task and the manner to which the feedback helps satisfy that desired goal (e.g., understanding the error-detecting and -correcting process by helping the learner confirm an error was made versus evaluating which specific factors contributed to that error).

Decades of research have been dedicated to understanding the optimal amount (how much information) and timing (scheduling of information delivery) of augmented feedback that a learner should receive. Earlier behavioural perspectives on feedback, particularly revolving around correcting errors, suggested that providing more information (Thorndike, 1927) and reinforcement (Skinner, 1951) would produce better learning. However, these traditional views did not take into account the complexities of human learning and the consequences of adopting such paradigms (e.g., augmented feedback dependency as suggested by the *guidance hypothesis*) (Salmoni et al., 1984). To minimize the negative learning effects of receiving too much information (i.e., feedback dependency) (Winstein & Schmidt, 1990), there have been different methods suggested for delivering reduced-frequency feedback that still produce effective learning (e.g., faded, bandwidth, summary/average, self-controlled) (Schmidt & Lee, 2014). A faded feedback schedule guides the learner towards the beginning of practice by providing feedback after every movement trial before gradually reducing it as practice progresses (Winstein & Schmidt, 1990). The bandwidth feedback method (feedback that is only provided when errors surpass a pre-determined range/'band' of correct performance) is especially beneficial for learning if the learner is provided with a larger error tolerance (Sherwood, 1988). Scheduling the feedback in this manner forces learners to use their own inherent feedback to help develop error-detection and -correction mechanisms so that they minimize their dependency on external sources, which has been shown to be detrimental to learning (Salmoni et al, 1984). Interestingly, the bandwidth feedback technique has also produced effective learning beyond the common reduced-frequency feedback explanation (Lee & Carnahan, 1990). A method that might be less disruptive to practice consists of delivering performance information after a pre-determined amount of practice trials have been completed; either by providing performance information about each individual trial during this pre-determined time or an average of those completed trials (Schmidt, Lange, & Young, 1990; Schmidt, Young, Shapiro, & Swinnen, 1989). A final technique that tends to be more commonly adopted in applied settings is allowing the learner to determine when feedback should be delivered during practice (i.e., self-controlled as opposed to instructor-controlled feedback) (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995). There is a large body of evidence that has shown that learning is facilitated when the learner is provided with the opportunity to choose when feedback is received (Chiviacowsky & Wulf, 2002; Janelle et al., 1997; Janelle et al., 1995; Patterson & Carter, 2010). This benefit could be due to numerous reasons including the learner's readiness to receive the feedback or due to increases in motivation because the feedback delivery is now personalized to one's learning needs. As a result, under a self-controlled feedback practice schedule, the learner might interpret the feedback that he/she requests and receives as being more meaningful.

The various feedback scheduling methods all contribute performance information with a common aim to augment the learning process. However, the unique modifications of how much and when the information should be delivered to the learner will depend on the context including the available resources, the skill of the learner, task complexity, task goal, and the amount of time that can be dedicated to task practice. In summary, augmented feedback has long been viewed as an ideal learning technique to help provide the learner with additional *information* about task performance and error-detection and -correction processes that would ultimately enhance the learning process. However, as new research lines emerge, most researchers are beginning to agree that feedback offers the learning process properties that are beyond just corrective content.

1.5 – FEEDBACK THROUGH A MOTIVATIONAL LENS

Outside of the motor learning domain, there has been an extensive line of research recognizing the motivational properties that augmented feedback can offer. Feedback has been suggested to provide the learner with a greater sense of confidence, encouragement and enjoyment; help minimize boredom; and even modify goal pursuit, task processing and actual performance (Cimpian et al., 2007; Dweck & Leggett, 1988; Fishbach et al., 2010; Graham & Golan, 1991; Hutchinson et al., 2008).

Until the last several years, this area of research had been widely ignored in motor learning studies, which included tests of retention, since motivation was thought to only elicit temporary effects on performance (Schmidt & Lee, 2011). However, recent motor learning studies have provided evidence for both the motivational properties of feedback, particularly related to self-controlled feedback schedules, and the direct impact on motor learning (examined through delayed retention and transfer tests without feedback) (Chiviacowsky & Wulf, 2007; Patterson & Carter, 2010; Saemi, Porter, Varzaneh, Zarghami, & Maleki, 2012; Sanli, Patterson, Bray, & Lee, 2013).

Chiviacowsky and Wulf (2002) offered initial evidence for the role of feedback-related motivational factors on learning and proposed a motivational explanation for the effectiveness of the self-controlled feedback schedule. One of the unique features of this type of schedule is that the delivery of feedback is personalized to the learner's needs and this benefit has been suggested to provide the learner with value that is beyond an informational level. In other words, feedback provides the learner with more than just informational properties related to his/her task performance. In a post-study interview, the self-controlled feedback participants in the Chiviacowsky and Wulf (2002) study reported that they predominantly asked for feedback following what they believed to have been "successful" trials (relative to the task goal). In a 2007 follow-up study, Chiviacowsky and Wulf showed that the benefits of receiving feedback following perceived good trials was independent of whether or not feedback was self-controlled, which provided evidence for the motivational properties of feedback itself (i.e., feedback that confirms successful performance). Badami, VaezMousavi, Wulf and Namazizadeh (2011) extended this research by measuring motivation and found that intrinsic motivation, particularly perceived competence, significantly increased in learners receiving feedback following their good trials. Self-efficacy (task-specific confidence, which is discussed in Section 1.9) has also been reported to be higher in those receiving feedback following good trials compared to poor trials (Saemi et al., 2012). The beneficial effects of receiving feedback following perceived good trials has been replicated on several occasions (Chiviacowsky, Wulf, & Lewthwaite, 2012) as well as extended to children (Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008) and older adults (Chiviacowsky, Wulf, Wally, & Borges, 2009).

Although there is a growing body of evidence for the motivational influences related to how learners use feedback during the learning process (e.g., learners prefer to receive feedback after good performances), the feedback content and the nature of the feedback itself can also have specific motivational influences on learning (e.g., personal performance feedback versus comparative feedback to either an objective or normative standard) and therefore, warrants clarification.

1.6 – FEEDBACK THROUGH A SOCIAL LENS

A prominent theory in social psychology (i.e., social comparison theory) postulates that people have a need to accurately self-evaluate themselves (e.g., their attributes, performance) and that this need is best satisfied when people can compare themselves against an objective criterion (Festinger, 1954). For example, when an objective standard is not available, humans prefer to compare themselves with others, especially to those who they perceive to be similar (Festinger, 1954). This comparative information, which begins to be used at an early age, is fundamental to the learning process. For example, when young children are learning how to perform a simple motor task they tend to compare themselves to other similarly skilled children (France-Kaatrude & Smith, 1985) and this interest in using comparative information increases with age (Ruble, Feldman, & Boggiano, 1976). However, there is also research to suggest that despite performance feedback or an objective criterion being available, learners still use social-comparative feedback. For instance, research dating back to 1898 provides one of the first accounts of the social influences of behaviour (social facilitation), where in the presence of a social setting, learners perform better than they do in the absence of others (this is despite having performance feedback or an objective criterion) (Triplett, 1898).

Due to the abundance of social information that is consistently available, people often receive social-comparative information even without deliberately seeking it themselves (e.g., receiving group average feedback after performing a task) (Suls, Martin, & Wheeler, 2002). Receiving social-comparative feedback (also termed normative feedback) has consequences for how a learner will judge personal performance, which can translate to modifications in perception and/or actual behaviour. Lamarche and colleagues (Lamarche, Gammage, & Adkin, 2011; Lamarche, Huffman, Eliasz, Gammage, & Adkin, 2008) found that for a simple upright standing task, receiving social-comparative feedback, regardless of actual performance, altered perceptions (e.g., perceived balance stability) but not actual balance measures. However, there is also evidence that social-comparative feedback is potent enough to modify actual behaviour, including performance outcomes on cognitive and decision-making tasks (Bandura & Jourden, 1991; Escarti & Guzman, 1999; Lamarche, Gionfriddo, Cline, Gammage, & Adkin, 2014; Smith, Kass, Rotunda, & Schneider, 2006) and motor tasks (Escarti & Guzman, 1999; Hutchinson et al., 2008; McKay et al., 2012; Stoate et al., 2012).

A recent line of research has also revealed that social-comparative feedback has consequences on the long-term performance of motor tasks (i.e., motor learning). In 2010, Lewthwaite and Wulf provided the first demonstration that false social-comparative feedback can modify the motor learning process. More specifically, when learners were provided with positive social-comparative feedback compared to negative or no social-comparative feedback, the better-than-average performance feedback facilitated their learning of a balance task (inferred through superior performance on a delayed retention test) (Lewthwaite & Wulf, 2010). Receiving positive compared to negative social-comparative feedback has also been shown to facilitate transfer performance on a sequence key-pressing task (Wulf et al., 2010). Eliasz (2012) extended this work by including a control group and delivering the false social-comparative feedback at a lower frequency (i.e., five instances compared to eight) during the key-pressing acquisition phase. The experimental task also included a task-switching algorithm during acquisition so when learners satisfied the task goal they were rewarded with a switch to practice a new pattern (failure to satisfy the task goal resulted in repeating the same pattern). Based on the nature of task-switching algorithm, more task-switching was viewed as being more beneficial to the learning process for two main reasons: 1) it meant that the learner was satisfying the task goal more often, and 2) it also meant that the learner was engaged in more random practice (compared to blocked), which has been consistently shown to be better for task retention (Battig, 1979; Lee & Simon, 2004; Shea & Morgan, 1979). The results demonstrated that regardless of actual performance, providing learners with false positive social-comparative feedback not only enhanced delayed retention performance (i.e., learning) of the sequential timing task but also overrode a less favourable practice schedule (i.e., blocked practice). In other words, learners in the positive social-comparative group engaged in significantly less task-switching/more blocked practice compared to those in the other two groups, which meant that they also had a lower occurrence for successfully satisfying the task goal. Despite engaging in a practice schedule that resulted in less goal attainment and as a result more blocked practice, the better-than-average feedback still facilitated learning. The beneficial learning effects that are experienced as a result of receiving positive social-comparative feedback have also been extended to children (Avila et al., 2012) and older adults (Experiment 1 in Wulf et al., 2012). Interestingly, this body of literature supports other evidence that shows people are positively biased in the way that they use social feedback to judge themselves (Korn, Prehn, Park, Walter, & Heekeren, 2012).

1.7 – ALTERING THE MINDSET

A learner's mindset can be deliberately modified during the learning process (e.g., through feedback) or prior to learning a skill (e.g., through instructions) (Drews, Chiviacowsky, & Wulf, 2013; Eliasz, 2012; Wulf et al., 2012; Wulf & Lewthwaite, 2009). Both of these techniques when used to alter the state of mind can have profound influences on psychological and behavioural outcomes. As described in the previous section, adopting a better-than-average mindset during practice tends to enhance perceptions, performance and learning (Avila et al., 2012; Eliasz, 2012; Hutchinson et al., 2008; Lamarche et al., 2011; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012).

Altering a learner's pre-existing belief system and therefore his or her mindset *prior* to skill acquisition can also modify how the learner will approach the task. Priming the state of the mind can be accomplished through instructions. One method is to prime learners with motivational information to make them believe that they are likely to perform the upcoming task a certain way compared to their peers. Although this technique uses social information to alter how one thinks about him or herself, it differs from feedback that is comparative in nature (i.e., social-comparative feedback). For example, older adults who were told that "active people like you, with your experience, usually perform well on this task" prior to practicing a balance task experienced more effective learning for that task (as demonstrated on a retention test) (Experiment 2 in Wulf et al., 2012). Another instructional method includes priming learners with specific statements that will focus their attention towards only self-related conditions (i.e., how one thinks about his or her personal abilities). For example, Jourden, Bandura, and Banfield (1991) manipulated a learner's conception of ability through written instructions that were provided prior to the acquisition of a perceptual-motor task. The instructions led the learner to believe that performance on the pursuit rotor task either measured his/her inherent ability to process dynamic information or that the task represented a skill that could be acquired (or improved) with practice. Those who were primed with the mindset that the perceptual-motor task was a learnable skill exhibited greater performance gains and more positive self-reactions compared to those that approached the pursuit motor task as a representation of their natural ability (Jourden et al., 1991). These results have been extended to motor learning in children learning a throwing task (Drews et al., 2013) and young adults learning a balance task (Wulf & Lewthwaite, 2009). Both studies demonstrate that learning is enhanced (inferred through performance on retention tests) when the task is viewed as being acquirable rather than attributed to inherent ability (Drews et al., 2013; Wulf & Lewthwaite, 2009).

A similar concept regarding mindsets has also been explored by Dweck (1999, 2002, 2006). She differentiates between two mindsets (i.e., a growth mindset versus a fixed mindset), that once adopted by the learner during task pursuit, will influence how much effort, perseverance and challenge the learner is willing to put forth. A fixed (static) mindset reflects a belief that one has an innate ability to complete a skill (similar to the inherent ability concept), while a growth (dynamic) mindset reflects a belief that one can develop that skill over time (similar to the acquirable skill concept) (Dweck, 2006). Generally this body of literature suggests that learning across various parameters tends to be enhanced when a learner adopts a growth mindset (instead of a fixed mindset) and believes that learning a skill represents a capability that is malleable and acquirable (instead of representing inherent ability) (Aronson, Fried, & Good, 2002; Cimpian et al., 2007; Dweck, 1999, 2002, 2006; Dweck, & Leggett, 1988; Good, Aronson, & Inzlicht, 2003; Jourden et al., 1991; Wulf & Lewthwaite, 2009).

The mindset that learners adopt prior to skill acquisition can also cognitively prepare them to use specific strategies when processing different types of events as either a gain or a loss. Regulatory focus theory suggests that a learner adopts one of two mindsets (or foci) when pursuing a goal: a promotion or prevention focus (Higgins, 1987, 1997, 1998). Learners can have a disposition to using one of these foci (e.g., based on personality) or experimental protocols can be used to activate the use of one of these foci (e.g., based on a situational manipulation). With a promotion focus, the learner will be primarily inclined to pursue goals with a particular sensitivity to positive outcomes (Higgins, 1997, 1998). A learner with this type of self-improvement mindset will typically approach success as a gain. In contrast, a learner with a prevention focus is sensitive to negative outcomes, inclined to adopt defensive strategies and will typically be orientated to prevent losses (e.g., avoid errors) (Higgins, 1997, 1998). In other words, this means that a learner with a promotion focus will be most sensitive to positive feedback whereas a learner with a prevention focus will be most sensitive to negative feedback.

Manipulating a learner's mindset prior to skill acquisition can also be accomplished through the experimental induction of different emotional states, which have been shown to influence the learning process (McConnell & Eva, 2012). Emotions are feelings, moods or affective states that impact cognitive processes and behaviour (Izard, 2009; Loewenstein, Weber, Hsee, & Welch, 2001); however, some researchers have also argued that emotions are independent from reason and can be processed automatically or unconsciously (Bargh & Williams, 2007; Gross, 1999; Zajonc, 2000). Regardless of the actual mechanisms involved in emotion regulation, these affective states or moods have been demonstrated to play an important role in cognitive functioning related to memory, attention and decision-making processes (LeBlanc, McConnell, & Monteiro, 2015).

1.8 – THE POWER OF POSITIVE INTERPRETATIONS

The previously-outlined studies that have examined the influence of self-controlled feedback schedules (Section 1.5), social-comparative feedback (Section 1.6) and instructional/mindset manipulations (Section 1.7) generally seem to suggest that information that is positive in nature adds unique benefits to the learning process. More specifically, receiving feedback following perceived good trials (Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Patterson & Carter, 2010; Saemi et al., 2012), adopting a better-than-average mindset during acquisition (Avila et al., 2012; Eliasz, 2012; Hutchinson et al., 2008; Lamarche et al., 2011; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012), and altering the mindset to a reflect a more cognitively positive (or flexible) outlook prior to acquisition (Aronson et al., 2002; Cimpian et al., 2007; Dweck,1999, 2002, 2006; Dweck, & Leggett, 1988; Good et al., 2003; Higgins, 1987, 1997, 1998; Jourden et al., 1991; Wulf & Lewthwaite, 2009) results in more effective behavioural outcomes (e.g., better task performance, learning, and transfer).

Inducing a positive state of mind (e.g., through altering perceptions, emotions, motivation) is not only preferred by learners (Kimchi, 1992; Taylor & Brown, 1988) but *positive thinking* seems to help learners use the information they have available to them more effectively (e.g., feedback). A positive state of mind also helps learners optimize their approach towards a task (e.g., the types of strategies they choose to implement) (Pekrun, Goetz, Titz, & Perry, 2002) and makes them more resilient to challenging events (Yeager & Dweck, 2012). There is also evidence that individual differences help determine how information is internalized and responded to. For example, individuals with higher dispositional optimism compared to pessimism have a greater tendency to experience more positive mental and physical health outcomes (Scheier & Carver, 1985), and even perceive placebo treatments as being more beneficial (e.g., reporting better sleep quality in a placebo condition) (Geers, Kosbab, Helfer, Weiland, & Wellman, 2007).

The cascading benefits of positive appraisals (Taylor & Brown, 1988) have caused a surge of research in various fields promoting positive psychology interventions (including strategies for coping and cognitive reframing). There have also been several explanations proposed for why positive thinking/affect facilitates behaviour including suggestions that this frame of mind expands attentional resources, enhances motivation, protects the ego, and ensures consonance (see the following subsections – 1.8.1, 1.8.2, 1.8.3, 1.8.4).

1.8.1 – '*Expands' Attention*

Research in emotions generally suggests that positive affective states expand the scope of attention (Fredrickson, 2001; Fredrickson & Branigan, 2005), while negative affective states narrow the attentional spotlight (Easterbrook, 1959). Specifically, positive affect manipulations broaden cognition, enhance creativity and cognitive flexibility (Isen, 1987, 1990), and allow individuals to focus on more global concepts (i.e., focus on the 'forest' as opposed to the 'trees') (Gasper & Clore, 2002). These types of manipulations have also been applied to various sport contexts. For example, when learners were primed with positive information suggesting that a famous golfer had used the equipment they were going to be using for a golfing experiment (possibly inducing positive affect), they perceived the size of a golf hole to be bigger prior to putting and even performed the golfing task better than the control condition (Lee, Linkenauger, Bakdash, Joy-Gaba, & Proffitt, 2011). These primes can even be more generic in nature. For example, individuals being told that they will likely perform better under pressure improved their throwing accuracy compared a control condition in an experimentally-induced pressure situation (McKay et al., 2012). Furthermore, the cognitive processing benefits induced by situational manipulations of positive affect or emotion have also been extended to personality traits, where those who are more optimistic tend to adopt a global rather than local bias (Basso, Schefft, Ris, & Dember, 1996). Feedback implying success also triggers learners to adopt a global perspective (Derryberry & Tucker, 1994). This finding might explain some of the research that has been conducted over the last decade by Witt and colleagues in the realm of sport performance. These studies demonstrate that following *successful* performance, individuals perceive target sizes to be larger (e.g., football uprights, golf hole) (Witt & Dorsch, 2009; Witt, Linkenauger, Bakdash, & Proffitt, 2008) and equipment such as a baseball also appearing bigger (attributing the size of the baseball to a grapefruit rather than a black-eyed pea) (Witt & Proffitt, 2005).

This body of research provides evidence that there is a very close linkage between the mind and the body. Positive information/states are suggested to optimize task performance because the task priming or cognitive appraising results in attention broadening (where the environment itself and perhaps aspects within the environment are perceived more globally).

1.8.2 – *Enhances Motivation*

Positive emotions can enhance motivation (Pekrun et al., 2002). A positive state of mind, induced using a variety of techniques (reviewed throughout this chapter), can help increase the perception of success and competency, which satisfies fundamental psychological needs (Deci & Ryan, 2008; Ryan & Deci, 2000). In the motor learning and psychology domains, creating a sense of autonomy by providing learners with opportunities to control aspects of their practice (e.g., self-controlled feedback studies) (Chiviacowsky & Wulf, 2002;

Janelle et al., 1997; Janelle et al., 1995; Patterson & Carter, 2010) or even providing them with options to choose from, whether these choices are related to the task (Cordova & Lepper, 1996; Lee, Eliasz, Gonzalez, Alguire, Ding, & Dhaliwal, 2016; Tafarodi, Milne, & Smith, 1999) or task-irrelevant (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015), has been demonstrated to enhance the learning process. Interestingly, there is also evidence for additive learning effects when different enhanced-learning techniques are combined. For example, providing learners with choice in addition to positive social-comparative feedback produced additive benefits for the learning process compared to only providing positive social-comparative (Wulf et al., 2014).

The importance of these motivational benefits, particularly for motor learning, has led to a very recent theoretical contribution by Wulf and Lewthwaite (2016): the OPTIMAL (Optimizing Performance through Intrinsic Motivation and Attention for Learning) theory of motor learning. Wulf and Lewthwaite (2016) provide a strong theoretical argument for creating optimal conditions for learning by merging two lines of research (both of which are relevant to this work): 1) motivational/autonomy support, and 2) attentional focus. The first line of research (motivational/autonomy support) has been comprehensively reviewed throughout this chapter. To summarize, a large body of evidence has been provided to suggest that enhancing motivation and autonomy using various manipulations such as self-control, choices, and positive feedback and mindsets, improves various levels of the learning process (Aronson et al., 2002; Avila et al., 2012; Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Dweck, 1999, 2002, 2006; Eliasz, 2012; Hutchinson et al., 2008; Janelle et al., 1997; Janelle et al., 1995; Lee et al., 2016; Lewthwaite et al., 2015; Lewthwaite & Wulf, 2010; Patterson & Carter, 2010; Saemi et al., 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2009; Wulf et al., 2010, 2012). The second line of research is related to attentional focus (from a motor behaviour perspective). The robust body of literature on attentional focus (Wulf, 2013 provides a comprehensive review) generally demonstrates that learning is enhanced when individuals adopt an external focus of attention (attention towards the intended movement effect) relative to an internal focus of attention (attention towards body movements and a focus on the self) during motor skill acquisition. With motivational factors having had a long history of being dismissed in the motor learning domain, the OPTIMAL theory (Wulf & Lewthwaite, 2016) is timely in its conception to account for emerging research that is incorporating motivational and attentional variables. Considering both psychosocial and behavioural factors, particularly in union, will provide a better understanding of these unique interactions that shape the complexities of human learning.

1.8.3 – *Protects The Ego*

Cognitive biases can distort the way in which one perceives the world. Some of these cognitive biases, whether predisposed or developed throughout the human experience, serve to protect the ego. One ego-protective belief is the self-serving bias (Miller & Ross, 1975), which is the tendency to view oneself in an advantageous manner and protect the ego from threat. This bias attributes favourable information (e.g., success) to internal or personal factors and unfavourable information (e.g., failure) to external factors (Campbell & Sedikides, 1999; Weiner, 1985). For instance, receiving a good grade on a test would be attributed to test preparation and ability, whereas a bad grade would be attributed to the test itself being unfair.

Research suggests that individuals, regardless of their self-esteem, are biased towards positive information (Jussim, Yen, & Aiello, 1995; Sedikides, 1993; Taylor & Brown, 1988). For instance, when individuals are provided with a choice regarding which type of information they prefer to receive (with respect to themselves), they consistently choose positive over negative (Sedikides, 1993) and they also accept more causal responsibility for success (Miller & Ross, 1975). This research suggests that positive information is typically favoured because it may potentially enhance self-esteem in addition to serving as a protective mechanism for threats against the ego. Another reason for this favouritism is that internal attributions (those attributed to success) typically produce more positive affect (McFarland & Ross, 1982), which in turn has been suggested to broaden attention (reviewed in Section 1.8.1).

It is proposed that the self-serving bias is driven by both cognitive (non-motivational) *and* motivational processes (Shepperd et al., 2008). From a strictly cognitive perspective, people choose to make self-serving attributions based on outcomes, that they evaluate objectively, which are consistent with their expectations (Miller & Ross, 1975; Shepperd et al., 2008) – these are typically positive expectations (Shepperd et al., 2008). From a motivational perspective, it is proposed that people are driven to preserve self-esteem through self-enhancement (upholding one's self-worth) and self-presentation (impression management) (Shepperd et al., 2008). Individual differences also seem to be involved with the self-serving bias, where those who have high self-esteem view receiving positive feedback regarding themselves as being more accurate than negative feedback (Jussim et al., 1995). It is also suggested that those with high self-esteem are more susceptible to the self-serving bias (i.e., the self-serving bias is magnified) because they are driven to invest more effort to protect/maintain a higher level of self-esteem (Campbell & Sedikides, 1999).

Self-serving bias is a potential explanation for why positive thinking is adopted and beneficial towards behaviour. Although self-enhancement (tendency to see oneself as better than others and gathering information to confirm that) influences the self-serving bias, protecting the ego is an even more potent driver (Sedikides, 1993), particularly for countering or minimizing threats to the ego (i.e., negative information). In short, there is little doubt that one is fundamentally wired to protect his/her ego.

1.8.4 – *Ensures Consonance*

Related to protecting the ego, learners choose belief systems that will correspond with their actions so that they experience a level of congruency in their day-to-day lives. Typically people structure their belief systems to consist of positive expectations, regardless on their prior experience (Shepperd et al., 2008), which may be an antecedent to successful performance (Section 1.8 and Subsections 1.8.1, 1.8.2, 1.8.3). Positive thoughts and experiences create consonance (congruency), which does not require an individual to search for *why* a positive outcome occurred (Shepperd et al., 2008). Individuals favour and strive towards having a state of consonance (Gawronski, 2012). However, if cognitions and outcomes are incongruent with each other, especially for a task that is self-chosen, individuals will use various mechanisms that will minimize or avoid the conflicting states of belief and/or action, in order to return to or maintain consonance (Frey, 1986; Shepperd et al., 2008). Individuals will even use several techniques to try and diminish the intensity of *prior* negative experiences (Taylor, 1991) so that they minimize inconsistency (states of dissonance) for future experiences. Cognitive dissonance is a negative psychological state where cognitions and actions are inconsistent with each other (Festinger, 1957). Aronson (1968, 1999) further suggested that the dissonance is created as a result of self-inconsistency (i.e., the behaviour is inconsistent with one's self-concept) and proposed the self-consistency theory as a motivational alternative to explain dissonance effects. He also proposed that individuals do not experience dissonance with the same intensity due to varying levels of self-esteem (Aronson 1968). Although there is much debate as to the underlying reasons of dissonance, researchers do agree that there is a discrepancy that occurs and it provokes negative affect. Individuals find dissonance (negative affect) emotionally aversive so they are motivated to use strategies (changing behaviour/cognitions, or adding new cognitions) to avoid or reduce the inconsistencies and make them more congruent (Festinger, 1957; Gawronski, 2012). The motivation to avoid/reduce cognitive dissonance (and maintain consonance) could be another potential explanation for why positive thinking is adopted and beneficial towards behaviour.

1.9 – SELF-EFFICACY

Social cognitive theory addresses both the development of competencies and the regulation of action, and suggests that we are active rather than passive agents within our environments (Bandura, 1986). The central component of this theory is self-efficacy, which is an individual's confidence in his or her own capability to execute a behaviour relative to a specific activity (Bandura, 1986, 1997). This motivational construct is based upon the belief that one has control over outcomes that can result in a specific behaviour. Although self-efficacy represents one's perceived and not actual capability, it is a robust predictor of behaviour that also plays an important role in motivation, emotional regulation and coping mechanisms (Bandura, 1997; Moritz, Feltz, Fahrback, & Mack, 2000; Schunk, 1990, 1995).

Self-efficacy not only correlates with performance but it is also an important psychological factor that influences the degree to which people will pursue specific tasks. For instance, the more certain an individual is about his or her capability, the more effort he/she will dedicate towards the task, resulting in a greater chance of accomplishment (Bandura, 1989). Even in situations where a task is particularly challenging or performance dissatisfaction is high, a higher self-efficacy belief will result in a greater amount of effort expenditure (Bandura, 1986; Bandura & Cervone, 1986; Escarti & Guzman, 1999; Schunk, 1990). In contrast, a lower self-efficacy belief will result in a tendency to want to avoid that task, regardless of actual skill (Schunk, 1990).

1.9.1 – *Sources Of Self-Efficacy*

Although these cognitive beliefs develop across experiences, not all sources of information will shape self-efficacy in the same manner. Bandura (1986, 1997) has identified four determinants of self-efficacy: previous (mastery) experience, vicarious experience, social (verbal) persuasion, and physiological/emotional states (Bandura, 1997, 1986). The strongest source of self-efficacy, which is highly resistant and predictable, is an individual's previous experience (Bandura, 1997). Successful (mastery) experiences increase self-efficacy beliefs, while repeated failures, particularly in the early phase of competency development, tend to weaken self-efficacy beliefs (Bandura, 1997, 2010). The second determinant of self-efficacy is vicarious experience, which is learning through observation (Bandura, 1997). The learner compares him or herself to the model they are observing and indirectly experiences the model's behavioural outcome. For instance, if the model experiences task success then the learner's self-efficacy for that particular task will also increase. The more similar the learner is to the model being observed, the more likely the learner's self-efficacy beliefs will be impacted. Learners also acquire a lot of information about their own capabilities through social comparisons (i.e., comparing themselves to a group average) (Bandura, 1997). The third determinant of self-efficacy, social/verbal persuasion, is the feedback that a learner receives from a social source (Bandura, 1997, 2010). The influence of this source will highly depend on the credibility of the feedback provider (Bandura, 1997). In addition, this particular source of self-efficacy becomes more potent if the learner receives different forms of social persuasion (reinforcing the feedback provider's message) (Bandura 1997, 2010). The influence of social-comparative feedback, which is the focus of this dissertation, operates at both the level of vicarious experience (includes social comparisons) and social persuasion (feedback is typically from a social source) to influence a learner's self-efficacy. Finally, the least effective source of enhancing self-efficacy beliefs is the *interpretation* of one's own physiological/emotional states. Physical or psychological states, particularly if interpreted as negative, tend to lower self-efficacy beliefs (Bandura, 1997; Maddux, 2002). In summary, these four sources of information do not establish self-efficacy beliefs however, they do (depending on the strength of the source) influence cognitive beliefs associated with one's self-efficacy.

1.10 – INDIVIDUAL DIFFERENCES

Much of the earlier research on individual differences focused on approaches to personality categorization based on trait levels. The two most popular taxonomies that have dominated the literature include the three-factor model (Eysenck & Eysenck, 1975; Eysenck, Eysenck, & Barrett, 1985) and the five-factor model/'the Big-Five' (Goldberg, 1990, 1992, 1993). The three-factor model categorizes personality according to three dimensions: *Extraversion*/Introversion, *Neuroticism*/Emotional Stability, *Psychoticism*/Socialization (Eysenck & Eysenck, 1975; Eysenck et al., 1985). The most widely used is the five-factor model, which identifies personality based on: Extraversion, Conscientiousness, Agreeableness, Neuroticism (Emotional Stability), Openness to Experience (Goldberg, 1990, 1992, 1993).

Individual differences (trait and/or state) can account for large or subtle variations in one's reaction to a situation (e.g., feedback). Most research acknowledges that individual differences will contribute to how feedback is interpreted; however, other than personality research, the majority of the research has focused on situational factors (i.e., state variables) when attempting to understand reactions to feedback. States are more transient and fluctuate based on the context/situation whereas traits are more stable/dispositional tendencies (Matthews et al., 2000). For instance, self-efficacy (reviewed in Section 1.9) is not a personality trait but rather a belief (state-like) in the ability to do a task-specific behaviour. Self-esteem, on the other hand is typically considered a trait, and is an individual's global evaluation or attitude towards oneself (Baumeister, Campbell, Krueger, & Vohs, 2003). It is also probably the most widely studied trait. Self-efficacy and self-esteem have both been shown to be related to motivation, which is often conceptualized on both state and trait levels. All three factors have been significantly involved in feedback research and as a result are incorporated within this dissertation.

1.11 – HIGHLY-MOTIVATED LEARNERS

High levels of self-efficacy, self-esteem and motivation (intrinsic and/or extrinsic) are all characteristic of highly-motivated learners (Arshadi, 2009; Bandura, 1997; Harrison, Konings, Molyneux, Schuwirth, Wass, & van der Vleuten, 2013; Moritz et al., 2000; Schunk, 1990, 1995; Shepperd et al., 2008). Although individual differences have been recognized as having important implications, they have often been ignored in well-developed theories of motivation (e.g., self-efficacy theory). Researchers in the last two decades have argued for the importance of understanding the influences of individual differences in motivation (particularly trait motivation) if motivational theories are going to advance forward (Heggestad & Kanfer, 2000; Kanfer & Ackerman, 2000).

The need to address a person-centered perspective (individual differences) in motivation research is required as motivational properties, both at the level of the situation and individual, can determine how feedback is perceived, internalized and responded to. For example, there is evidence that learners possessing high levels of motivation (whether that may be at a trait or state level) may not interpret feedback in the same manner (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002;

Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988). According to variations of the cognitive dissonance theory (see Subsection 1.8.4), if an individual is confronted with conflicting information regarding his/her cognitions, self-image and self-concepts, then this will create a negative psychological state of discomfort (termed 'dissonance') that will motivate the individual to try and resolve this discrepancy (since there is a preference to remain in consonance) (Aronson, 1968, 1999; Festinger, 1957; Frey, 1986; Gawronski, 2012; Shepperd et al., 2008). There is also evidence to suggest that the magnitude of resolving this dissonance is based upon state and trait motivation, with higher levels facilitating greater urgency to reduce dissonance (Frey, 1986; Harmon-Jones, 2012, Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2011).

These various lines of research suggest that there is an important yet unclear relationship between psychological variables (both state and trait) that influences how a learner uses feedback during the learning process. Motivation, which shares properties with these other psychological variables (e.g., self-efficacy and self-esteem), seems to be at the core of this relationship.

1.11.1 – *Medical Trainees*

To better understand the role of trait and state motivation during feedback delivery, and in turn, the learning process, this dissertation used highly-motivated learners to explore this relationship. Although much of the research in motivation has been focused on early education (e.g., elementary and high school level) to better understand how to teach and motivate students (particularly low-achievers), there is no discipline like medicine where motivation is represented as a fundamental core (e.g., even admission protocols incorporate strategies to better ensure that highly-motivated learners are selected).

Motivation is considered a critical component in medicine, both from a selection perspective (i.e., selecting the most motivated) and a training perspective (i.e., designing curricula to optimize performance, learning, transfer). The motivational profiles of medical trainees demonstrate that they represent a subset of learners that are highly-motivated (Ferguson, James, & Madeley, 2002; Harrison et al., 2013; Hutchins, 1964; Kusurkar, Ten Cate, van Asperen, & Croiset, 2011; Mattick & Knight, 2009; Moulaert, Verwijnen, Rikers, & Scherpbier, 2004; Sobral, 2004; Tanaka, Mizuno, Fukuda, Tajima, & Watanabe, 2009; Todisco, Hayes, & Farnill, 1995; Turner & Nicholson, 2011). As a result, this dissertation selected medical trainees to represent a group of highly-motivated learners.

1.12 – FEEDBACK DELIVERY IN APPLIED SETTINGS

Even without the inclusion of psychosocial variables like motivation, the feedback conversation itself is already complicated in nature. Providing feedback, particularly if the feedback is negative, is challenging from both the perspective of the feedback provider and the feedback receiver. Feedback becomes even more problematic in settings where conditions cannot be as readily controlled (unlike a traditional laboratory setting), since the delivery transpires across a variety of mediums. For example, in applied settings like heath care, feedback can be delivered individually or in group settings, during various levels of simulation training or virtual scenarios (online), at the bedside and at times, following low and high-stake assessments (Archer, 2010; Molloy, 2009). In addition to the context, there are also different types of techniques that are used to shape the feedback message including whether it is framed towards a performance or a learning goal, whether or not the feedback is comparative (to an absolute or relative criterion) and whether it is framed as being positive or negative (the valence of the feedback itself) (Lefroy, Watling, Teunissen, & Brand, 2015). Health care settings also involve additional complexities with respect to the feedback conversation (written or verbal) since the delivery of the feedback could be initiated by different sources (single or multi-sources) including experts/clinicians, peers, patients, or unknown sources (with human or non-human elements) (Archer, 2010; Lefroy et al., 2015). Clinical settings are unique in that there is often a relationship that has been formed between the feedback provider and receiver – whether this is a relationship between colleagues, a clinical educator and a trainee, or a clinician/trainee and a patient. Protecting these relationships often becomes a priority and the feedback conversation, which is often conceptualized as being difficult, becomes neglected. The tensions associated with the feedback conversation are also often perceived as being uncomfortable or even feared, particularly by clinical educators (Ende, 1983; Molloy, 2009). It is therefore not surprising that several studies have reported that medical trainees are often not satisfied with the type or amount of feedback that they receive during their training (Bing-You & Trowbridge, 2009; Cantillon & Sargeant, 2008; Delva et al., 2013; Gil, Heins, & Jones, 1984; Isaacson, Posk, Litaker, & Halperin, 1995; Kogan, Bellini, & Shea, 2000; Robins, Gruppen, Alexander, Fantone, & Davis, 1997; Sumit, Henke, Ailwadi, Dimick, & Colletti, 2004). Due to the challenges of delivering personalized feedback (e.g., tensions, lack of resources), a more common alternative that is incorporated into medical training is the delivery of social-comparative feedback (Harrison et al., 2013). Providing trainees with their performance scores relative to their peers is convenient for the educators as this becomes an efficient way to deliver unbiased/uniform *feedback* information to all trainees and subsequently avoids a less desirable feedback conversation. Knowing how performance fares against the average is also often requested and preferred by trainees (Raat, Kuks, & Cohen-Schotanus, 2010; Watling, 2014a). However, one overlooked consequence of social-comparative feedback is that the trainee is left to interpret its meaning.

1.13 – RECEIVING AND RESPONDING TO FEEDBACK

Effective feedback should include a feedback message that is timely, specific, constructive, related to a goal, task-relevant (not judgmental towards the learner), and actionable (providing the learner with suggestions for improvement) (Archer, 2010; Latting, 1992; Lefroy et al., 2015; Molloy, 2009). However, in order for the feedback interaction to be *successful*, it has to be approached as a conversation, where the feedback translation and reaction are just as important as the delivery itself. Often research aimed at understanding feedback focuses on the delivery (the message and the feedback provider); however, in order to fully understand the dynamics of the feedback conversation, it is critical to also understand the perspective of the feedback receiver (the reactions and the feedback receiver).

1.13.1 – *Barriers To Receiving Feedback*

There is an assumption that the received feedback content is interpreted in the same manner as it is intended during delivery; however, this is often not the reality (McAllister, Lincoln, McLeod, & Maloney, 1997). The consequences of such a misalignment can have important implications on how feedback is (or is not) received. The most extreme consequence of this misalignment, and surprisingly not that uncommon in medical education, is that trainees may not even be aware that feedback has been or is being provided (Archer, 2010; Molloy, 2009). Patterson and Azizieh (2012) suggest that being aware of the feedback content (i.e., the information), regardless of the valence of the feedback (positive or negative), provides a greater impact on the learning process compared to the motivational properties that feedback can offer. Unawareness of feedback delivery could be due to several reasons including the feedback provider-receiver relationship and the different techniques that the provider might employ in order to protect the relationship (Archer, 2010; Molloy, 2009).

Other barriers to receiving feedback include the vast and varied array of emotions that are involved with how individuals interpret the feedback (Eva, Armson, Holmboe, Lockyer, Loney, Mann, & Sargeant, 2012; McConnell & Eva, 2012), which also relates to whether or not the receiver even accepts the feedback (Archer, 2010; Sargeant, Mann, Sinclair, van der Vleuten, & Metsemakers, 2008). These emotions, often fear-related, hinder feedback-seeking behaviours (generally defined as the proactive search for feedback information) (Archer, 2010; Crommelinck & Anseel, 2013; Eva et al., 2012). The nature of the feedback provider-receiver relationship may also contribute to the lack of feedback exchanges. For example, there may be potential repercussions that are associated with such exchanges, which include the trainee being labeled as possessing a lack of autonomy, knowledge and competency (Eva et al., 2012). These consequences, whether perceived or not, can have damaging disadvantages for a student's training trajectory and future career. As a result, in addition to the lack of *receiving* feedback that medical students often report, the lack of feedback-seeking behaviours has also been reported to be a major concern in medical education (Archer, 2010; Crommelinck & Anseel, 2013). This risky combination results in learning opportunities being lost due to what Ende (1983) has referred to as *vanishing feedback*.

1.13.2 – *Feedback Internalization And Response*

How feedback affects the learner is dependent on how the learner assesses and processes the information. Feedback interventions are not well understood since the internalization/interpretation and subsequent behaviour changes resulting from the feedback are also unclear (Bucknall, 2007; Crommelinck &

Anseel, 2013). This makes it difficult to predict when a feedback intervention will or will not benefit the learner.

Many of the feedback receiver's response inconsistencies are associated with the valence of the feedback (e.g., positive or negative), since every learner does not interpret it in the same manner. Furthermore, the strength and interpretation of the feedback valence will be based on a combination of the learner's affective state, past experiences and context (Archer, 2010; Bucknall, 2007; Zhou, 1998). There is no doubt that the learner's disposition will play an important role in feedback translation; however, the context will contribute to the intensity of the reaction. For example, a high stakes exam will elicit a different reaction to feedback (e.g., intensity) compared to a less formal context.

Another reason for the response inconsistencies could be due to a learner's feedback history. For instance, medical trainees often anecdotally report that they are used to receiving positive feedback. They also report having a preference and need for positive feedback and this could be due to their drive to uphold their self-esteem (which is at a higher level compared to other learners) (Archer, 2010; Boehler et al., 2006; Campbell & Sedikides, 1999). This suggests that trainees might lack the experience of receiving less favourable feedback, which could have significant repercussions on how they cope with negative feedback. The claims that medical students are not satisfied with the quality and quantity of feedback during their training have to be somewhat taken with caution as Boehler and colleagues (2006) have suggested that some of these self-reports of dissatisfaction might not necessarily be a reflection of the quality of feedback. Interestingly, their results demonstrated that satisfaction ratings for feedback delivery were significantly higher for trainees receiving compliments (praise) compared to complaints (Boehler, 2006). These findings suggest that feedback satisfaction ratings may be more of a representation of the receiver *not being able to cope* with receiving feedback that is meant to be corrective rather than it reflecting the quality of the feedback itself. These results are also in line with the motor learning research that suggests feedback provides motivational properties, which in turn enhance the learning process (Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Patterson & Carter, 2010; Saemi et al., 2012).

The affective consequences of feedback will impact how the message is internalized and responded to. Responding to feedback can be an emotional process, particularly when the feedback is misaligned with perceptions (e.g., creating cognitive dissonance as reviewed in Subsection 1.8.4). The effects of negative feedback on trainees can have long-lasting adverse consequences that are difficult to ignore and require a rather lengthy reflective process to aid with coping (Sargeant, Mann, & Ferrier, 2005; Sargeant et al., 2008). Even though the initial solution may be to cease the delivery of negative feedback, clinical educators need to be aware that attending to the emotions of trainees can create even greater barriers to the feedback culture (Ende, 1983).

1.13.3 – *Feedback Source*

When the feedback receiver attaches meaning to the feedback content, one of the most influential pieces of information that will be considered is the source of the feedback. Expert credibility is judged more critically than other sources (Watling, Driessen, van der Vleuten, & Lingard, 2012). If the feedback 'persuader' is perceived as being credible, powerful and trustworthy then the feedback is more likely to be accepted as well as interpreted as being accurate (Bannister, 1986; Ilgen, Fisher, & Taylor, 1979; Latting, 1992).

Feedback that is perceived as being believable (realistic) and from a credible source will have the greatest influence on self-efficacy beliefs (Bandura, 1997) and the best chance of changing an individual's behaviour (Frey, 1986). The competence/credibility of the source will also influence how much dissonance will be experienced. If the feedback provider is perceived as a credible source then there is a selective preference to receive consonant information and this information is perceived to be more meaningful (Frey, 1986), especially for individuals that have high self-esteem. The credibility will be evaluated by considering the feedback provider's expertise, reputability and trustworthiness (Bandura, 1997; Eagly & Himmelfarb, 1978; Latting, 1992; Maddux, 2002).

1.14 – SUMMARY AND THESIS AIM

Feedback is a powerful tool that has been shown to modify the learning process at both a psychological and behavioural outcome level. The preceding sections of this chapter use different lenses (informational, motivational, social) to provide a comprehensive review of the feedback literature. Since feedback is intended to be a conversation, this chapter also reviews feedback from the perspective of the receiver.

Feedback operates through the affective response it evokes (positive or negative feelings), which motivates behavioural change. Different lines of research have demonstrated that individuals prefer to receive positive information (Kimchi, 1992; Taylor & Brown, 1988) but more importantly, providing information that is positive in nature and enhances motivation (e.g., self-control, choices, positive feedback and mindsets) has been shown to improve various levels of the learning process (Aronson et al., 2002; Avila et al., 2012; Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Dweck, 1999, 2002, 2006; Eliasz, 2012; Hutchinson et al., 2008; Janelle et al., 1997; Janelle et al., 1995; Lee et al., 2016; Lewthwaite et al., 2015; Lewthwaite & Wulf, 2010; Patterson & Carter, 2010; Saemi et al., 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2009; Wulf et al., 2010, 2012). This dissertation explores a specific type of feedback, social-comparative feedback, which is commonly provided in many learning environments and has also been shown (i.e., positive social-comparative feedback) to enhance the learning process (Avila et al., 2012; Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012; Wulf & Lewthwaite, 2016). Interestingly, this body of research also suggests that individuals, even across various age groups, can cope with receiving information that they are performing worse than their peers (Eliasz, 2012; Lewthwaite & Wulf, 2010).

It has been proposed that the above-mentioned learning benefits occur because positive feedback has motivational properties, which enhances a learner's mindset through modifying psychological variables such as self-efficacy and subsequently affecting behavioural outcomes (Wulf & Lewthwaite, 2016). However, what is excluded from this proposition is the motivation at the *level of the learner*. Since motivation, at both a trait and state level, overlaps with other psychological variables such as self-efficacy (state) and self-esteem (trait), it is unclear how this relationship further influences the interpretation of feedback. Moreover, there is research that suggests that highly-motivated learners do not interpret feedback in the same manner as other learners that have been studied in the literature (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988). For instance, individuals with high self-esteem will react more adversely to situations that may be more threatening to the self (e.g., negative feedback) (Campbell & Sedikides, 1999).

These research questions have major implications in fields like medicine where motivation represents the core of the selection and training process. In other words, medicine designs curricula that aim to optimize learning in the highly-motivated learners that they select. It is within these critical training environments that feedback becomes the cornerstone of effective learning

(Cantillon & Sargeant, 2008). However, little is known about how highly-motivated learners like medical trainees interpret feedback (from a quantitative standpoint) and more importantly, how this impacts their learning. This dissertation focuses on the feedback conversation from the perspective of a highly-motivated learner with the aim to address the theoretical and applied gaps reviewed throughout this chapter.

1.15 – THESIS OVERVIEW AND SIGNIFICANCE

Using perspectives from psychology, sociology, motor learning and medical education as a framework, the overarching aim of this dissertation is to address the theoretical and applied gaps in the feedback literature. From a theoretical perspective, this dissertation explores how highly-motivated learners interpret and use feedback during the learning process. This warrants investigation, as there is evidence to suggest that highly-motivated learners, like the medical trainees used in this dissertation, may interpret social-comparative feedback differently than other learners. From an applied viewpoint, this dissertation addresses the learning implications of using social-comparative feedback in the feedback conversation. Social-comparative feedback is often provided in clinical settings because it is preferred (from both a teaching and learning perspective) (Harrison et al., 2013; Raat et al., 2010; Watling, 2014a); however, the implications for providing this type of feedback in clinical education are unknown (Lefroy et al., 2015). Surprisingly, a lot of feedback literature in the clinical education setting is based upon assumptions and the dominance of qualitative studies (Molloy, 2009). Although there is much value in understanding feedback from methodologically-sound qualitative studies (e.g., understanding how medical trainees in different contexts internalize, react and cope with feedback), these designs do not allow us to generalize phenomena that may otherwise help in predicting behaviour.

This research program includes the design of three studies aimed to examine the effects of social-comparative feedback during skill acquisition in a subset of highly-motivated learners (i.e., medical trainees). Our aim across all three studies was to alter the highly motived learner's mindset by providing deceptive social-comparative feedback to manipulate self-efficacy beliefs, and determine the influence this would have on the learning of procedural skills (i.e., suturing techniques). The research questions we asked built upon one another to first explore what the relationship between psychological variables (self-efficacy, self-esteem and motivation) and social-comparative feedback was relative to motor skill acquisition in this specific group of learners and next, to examine the intensity of the relationship based on the role of the task (Study 1 and 2) and lastly, the role of the feedback provider (Study 3).

The first study in the dissertation examined the degree to which social-comparative feedback affects highly-motivated learners during motor skill acquisition and also tested whether or not the features of the task were important during the interpretation of this feedback. Based on previous research (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012 (Experiment 1); Wulf & Lewthwaite, 2016), we hypothesized that positive social-comparative feedback would facilitate the learning process in highly-motivated learners compared to a control condition receiving no social-comparative feedback. Contrary to research findings suggesting that learners (non-medical) are not sensitive[1] to receiving negative social-comparative feedback (Eliasz, 2012; Lewthwaite & Wulf, 2010), we hypothesized that highly-motivated learners (medical trainees) would display more difficulty in coping with negative social-comparative feedback due to the intensity of the psychological inconsistency they would experience between the delivered feedback and their self-perceptions (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988). We also expected that this reaction would be greatest for a more training-relevant task (surgical skill task) compared to a less important task (computer key-pressing task) (Miller, 1976).

The second study in the dissertation used the same experimental paradigm to extend our initial results to a relevant medical education context (i.e., medical trainees learning basic suturing techniques). Based on the results of our initial study, we expected that removing the training-irrelevant task (computer key-pressing) would result in a stronger feedback effect, where the effect would be present across a longer retention delay and on the added clinical expert

[1] For both studies the majority of psychological and behavioural outcomes for the negative social-

assessment measures. Specifically, we expected that the adoption of a better-than-average mindset would not facilitate technical skill acquisition compared to the control condition; however, a below-average mindset would be detrimental to psychological and behavioural outcomes during surgical skill acquisition.

The final study examined whether the perceived credibility of the feedback provider (i.e., expert versus peer) played a role in how social-comparative feedback was being internalized by novice medical trainees. Based on Study 1 and 2 findings, we still expected a below-average mindset to be detrimental to psychological and behavioural outcomes during surgical skill acquisition; however, since effective feedback must be derived from a credible source (Bandura, 1997; Bannister, 1986; Eagly & Himmelfarb, 1978; Ilgen et al., 1979; Latting, 1992; Maddux, 2002; Watling et al., 2012), we hypothesized that trainees who received social-comparative feedback from a clinician (an expert) compared to a peer (a novice) would be more influenced by the "more credible" feedback (as determined by psychological and behavioural measures).

In summary, this program of research provides a meaningful direction for the intersecting lines of research in motivation, feedback, and learning. From a theoretical view, the findings of this dissertation help us to understand how motivation at the level of the learner influences skill acquisition – research that has been neglected in the motor learning domain. Understanding the feedback receiver also provides us with a more comprehensive understanding of the feedback conversation, which can have implications on feedback interventions that may be used for learners that are highly-motivated. From an applied perspective, the findings of this dissertation are particularly important in the context of feedback delivery and remediation in medical trainees (both of which are problematic in medical education). In a culture where the foundation is motivation, understanding how motivated learners react to the type of feedback that they usually receive during training is critical in advancing clinical education.

CHAPTER 2:

THE ROLE OF SOCIAL-COMPARATIVE FEEDBACK DURING THE MOTOR SKILL ACQUISITION OF DIFFERENT TASKS IN HIGHLY-MOTIVATED LEARNERS

2.1 – ABSTRACT

Social-comparative feedback has been shown to influence learner self-efficacy beliefs and motor skill acquisition (Avila et al., 2012; Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012; Wulf & Lewthwaite, 2016; Wulf, Lewthwaite, & Hooyman, 2013). Specifically, it has been suggested that motor learning is enhanced when learners, regardless of their actual performance, believe they are performing better than their peers with the beneficial effect of receiving positive social-comparative feedback on motor learning accruing for different learners (children, young adults, older adults) and across different tasks (balance, computer key-pressing, throwing) (e.g., Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, Experiment 2 in 2012). It is proposed that a better-than-average mindset enhances psychological constructs such as self-efficacy and motivation and in turn, actual behaviour (Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2016). However, there is also evidence to suggest that self-efficacy and motivation are related in terms of their affective influence on learning but this relationship and its subsequent outcomes remain unclear (Aronson, 1992; Bandura, 1997; Moritz et al., 2000; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Heggestad & Kanfer, 2000; Kanfer & Ackerman, 2000; Schunk, 1990, 1995; Steele, 1988). The goal of this study was two-fold: 1) to examine the role of social-comparative feedback on psychological and behavioural outcomes in a subset of highly-motivated learners (i.e., medical trainees) during motor skill acquisition, and 2) to test whether features of the task were important (i.e., basic laboratory task or technical skill task) during the interpretation of this feedback. Novice medical trainees were randomly assigned to three groups. The two social-comparative feedback groups were provided with manipulated feedback information to suggest to them that they were performing either relatively well or relatively poorly compared to their peers during both a commonly used motor learning laboratory task (sequential key-pressing) and a technical skill task (suturing). The control group performed the same two tasks but was not provided any social-comparative feedback. Results show that the trainees who were informed that they were performing worse than the average had more difficulty in learning the key-press patterns (i.e., they made significantly more errors in the delayed retention tests) and had more difficulty in performing a new procedural technique (i.e., they made significantly more hand movements and were slower on the transfer task). This negative social-comparative feedback group also reported significantly lower self-efficacy ratings for performing the key-pressing task (post-feedback manipulation) and significantly higher levels of frustration following the suturing transfer task compared to those in the other two groups. Our work suggests that contrary to previous research (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012; Wulf & Lewthwaite, 2016; Wulf et al., 2013), providing highly-motivated learners such as medical trainees with positive social-comparative feedback does not facilitate psychological and behavioural outcomes and can even be detrimental in some cases, whereas providing negative social-comparative feedback during skill acquisition can significantly and negatively moderate psychological variables, such as frustration and self-efficacy, as well as result in detrimental outcomes with respect to skill retention and transfer for different motor tasks.

2.2 – INTRODUCTION

A learner's mindset, those "beliefs, attitudes, and expectations" that shape one's interpretation of a skill acquisition situation is an important variable in influencing how much and how well the skills to-be-learned can be performed, retained and transferred. Different lines of research from various disciplines have demonstrated that the adoption of specific mindsets prior to or during the learning process can modify a learner's psychological and behavioural outcomes (Aronson et al., 2002; Bandura & Jourden, 1991; Cimpian et al., 2007; Dweck, 1999, 2002, 2006; Dweck, & Leggett, 1988; Escarti & Guzman, 1999; Good et al., 2003; Hutchinson et al., 2008; Jourden et al., 1991; Lamarche et al., 2014; McKay et al., 2012; Smith et al., 2006; Stoate et al., 2012; Wulf & Lewthwaite, 2009).

A powerful mediator of skill retention in this context (i.e., motor learning) is the manner in which learners receive feedback regarding their performance. Feedback not only provides a learner with information about the outcome of the movement that was executed (Salmoni et al., 1984) but it can also be considered to have motivational properties by providing the learner with a greater sense of confidence, encouragement, enjoyment, all while leading to modifying actual behaviour (Cimpian et al., 2007; Deci & Ryan, 1985; Dweck & Leggett, 1988; Fishbach et al., 2010; Graham & Golan, 1991; Hutchinson et al., 2008). Until recently, the motivational properties of feedback had been relatively understudied in the motor learning domain as motivation has typically been thought to only elicit temporary effects on performance (Schmidt & Lee, 2011, 2014). However, research has recently shown that feedback can have a direct motivational function that affects the *learning* of motor skills (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012; Wulf et al., 2013).

Interestingly, this emerging line of research has provided consistent evidence suggesting that learners largely benefit from receiving feedback that is positive in nature; somewhat contradicting the common traditional view of providing augmented feedback to primarily correct errors (Salmoni et al., 1984), where corrective information could be interpreted by learners as being negative feedback. More specifically, providing learners with feedback that is positive in connotation compared to negative or even no feedback (i.e., a control condition) is potent enough to facilitate learning. For example, providing learners (children, young adults, or older adults) with feedback following good compared to poor performance trials promotes motor learning as measured through performance on retention and/or transfer tests (Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Saemi et al., 2012). A more specific type of feedback that has also been shown to modify behaviour is social-comparative feedback (Festinger, 1954). Many experimental protocols have provided this particular type of feedback deceptively to reduce confounding variables that would likely impact the learning process (e.g., the effects of a learner's previous experiences and belief systems). Receiving false social-comparative feedback encourages the learner to believe that he/she is performing better or worse than the group average, regardless of actual performance, and thereby influencing the mindset and in turn, actual behaviour (Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Stoate et al., 2012; Wulf et al., 2010). Adopting a better-than-average mindset is also potent enough to override a less favourable practice schedule – one where the goal attainment occurs at a lower frequency and results in more blocked practice (Eliasz, 2012). Delivering positive social-comparative feedback has been shown to produce more effective behavioural outcomes (e.g., performance, learning, transfer) across different age groups (e.g., children, young adults, and older adults) (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010, Experiment 2 in 2012) and across different types of motor tasks such as balance, sequence learning, throwing, and running (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012). This body of research has also suggested that providing negative social-comparative feedback compared to no feedback (control condition) is not detrimental to the learning process and that learners across different ages are not sensitive[2], at least on a behavioural level, to receiving information that they are performing worse than the average (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf & Lewthwaite, 2016). Researchers have proposed that feedback, including positive social-comparative feedback, fulfills a motivational role that activates a positive psychological response, which directly impacts behaviour.

[2] Behavioural measures in the negative social-comparative condition do not reveal significant performance and learning detriments compared to a control condition.

A more specific form of motivation is examined in social cognitive theory, which addresses both the development of competencies and the regulation of action (Bandura, 1986). The central component of social cognitive theory is self-efficacy, which is an individual's belief in his/her own capability to execute a specific behaviour in a specific context (Bandura, 1986, 1997). Self-efficacy beliefs can be developed through four different information sources; including the feedback that one receives about his/her performance at either an absolute or comparative level (Bandura, 1986, 1997).

With over 10,000 investigations spanning 25 years, self-efficacy has been shown to play an important role in emotional regulation and coping mechanisms in addition to being a robust predictor of behaviour (Bandura, 1997; Judge, Jackson, Shaw, Scott, & Rich, 2007; Moritz et al., 2000; Schunk, 1995). Self-efficacy and motivation are also considerably related in terms of their affective influence on learning (Bandura, 1997; Schunk, 1990, 1991, 1995) and both have been proposed to explain the beneficial learning effects of the better-than-average mindset (Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2016); however, the relationship between the two constructs remains unclear. One reason could be related to how these *motivational* constructs are defined and studied. Self-efficacy is not a personality trait but rather a state-like belief (Bandura, 1986, 1997; Maddux, 2002), whereas motivation includes both trait (more stable characteristics) and state-like properties. Even though individual differences (i.e., person-centered approaches) in motivation have been suggested to influence self-efficacy beliefs, they have been largely ignored in this line of research. More specifically, cognitive theories of motivation like self-efficacy have failed to directly look at how a learner's motivation (both at a state and trait level) influences and interacts with his/her self-efficacy beliefs to alter psychological and behavioural outcomes. Similarly, motor learning studies exploring the motivational properties of feedback have also ignored the role that individual factors may have (e.g., instead only exploring these effects across different age groups). More importantly, if motivational explanations are to be proposed for why a better-than-average mindset facilitates learning while a below-average mindset is no different from a control condition (Wulf & Lewthwaite, 2016), then motivation at the level of the *learner* has to be taken into consideration.

We do not discount the importance of replication studies but we also acknowledge that testing motivation-related phenomena requires a shift in exploring beyond context (e.g., different tasks, different age groups). Despite the motor learning studies providing evidence that learners across all different ages are not sensitive to receiving information that they are performing below the average, there is also evidence to suggest that learners possessing high levels of motivation (whether that may be at a trait or state level) may not interpret feedback in the same manner (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988).

For instance, if an individual is confronted with conflicting information regarding his/her cognitions, self-image and self-concepts, then this will create a negative psychological state of discomfort (termed ‘dissonance’) that will motivate the individual to try and resolve this discrepancy (since there is a preference to remain in consonance). There is also evidence to suggest that the magnitude of resolving this dissonance is based upon state and trait motivation, with higher levels of motivation facilitating greater urgency to reduce dissonance (Frey, 1986; Harmon-Jones, 2012, Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011).

Therefore, the primary goal of this study was to use a more person-centered approach to examine the degree to which social-comparative feedback affects *highly-motivated learners* during motor skill acquisition. Based on previous research (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012 (Experiment 1); Wulf & Lewthwaite, 2016), we expected positive social-comparative feedback to still facilitate psychological and behavioural outcomes in highly-motivated learners compared to a control condition. However, contrary to this research (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf & Lewthwaite, 2016), we hypothesized that highly-motivated learners would interpret negative social-comparative feedback differently than the other learners studied in the literature. More specifically, based on the cognitive dissonance literature we suggested that highly-motivated learners would experience a more emotionally adverse reaction to receiving feedback that did not align with their own self-perceptions (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Steele, 1988). Therefore, the delivery of negative social-comparative feedback would create a negative psychological state (i.e., dissonance) and lead to psychological and behavioural detriments compared to a control condition. The secondary objective of this study was to test whether features of the task were important during the interpretation of this feedback. Previous studies relevant to this work did not measure situational motivation and used experimental tasks that may not have been viewed by learners as being important to master (e.g., computer key-pressing task). Based on this caveat, we expected that highly-motivated learners would be more sensitive to receiving social-comparative feedback for a more training-relevant task (Miller, 1976). To better understand the relationship between task and learner motivation, one of the experimental motor tasks we chose was a computer key-pressing task, which we had already used in a previous study with non-medical university learners (Eliasz, 2012). Using the same computer key-pressing methodology would allow us to make more direct comparisons between the two different groups of learners (i.e., non-medical and medical learners). Medical trainees were selected as a subset of learners who are highly-motivated (Ferguson et al., 2002; Hutchins, 1964; Kusurkar et al., 2011; Mattick & Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner &

Nicholson, 2011) with the primary contribution of the research being to assess social cognitive learning situations in this *type* of learner.

2.3 – METHODS

2.3.1 – *Participants*

Thirty novice pre-clerkship (years 1 and 2) medical trainees (16 female) with a mean age of 22.83 (*SD* = 3.09) from the University of Toronto participated in this study. Ethical approval was obtained from the home institutional site (i.e., McMaster University, #2012187) as well as the data collection site (i.e., University of Toronto, #28391). Exclusion criteria included colour-blindness and any condition that may have interfered with completing both a computer key-pressing task and suturing techniques. Data collection consisted of two sessions 24 hours apart for a total time commitment of approximately four hours. Each trainee was compensated 20 dollars upon study completion *(Session 1 and 2).*

To confirm that recruited participants were highly-motivated learners, prior to data collection all trainees completed a validated state motivation scale (Situational Motivation Scale, SIMS)[3] (Guay, Vallerand, & Blanchard, 2000) and a validated trait global measure of self-esteem (Single-Item Self-Esteem Scale, SISE) (Robins, Hendrin, & Trzesniewski, 2001) as a baseline measure of learner motivation[4]. Other motivational profiles of medical trainees were based upon the literature (Ferguson et al., 2002; Hutchins, 1964; Kusurkar et al., 2011; Mattick &

[3] The SIMS scale only measured state motivation related to the suturing task.
[4] See Table 2.1 for specific details.

Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner & Nicholson, 2011).

Trainees were randomly assigned to one of three groups, where during *Session 1* the:

Positive social-comparative feedback group (PF): received **positive** social-comparative feedback following both the key-pressing and suturing tasks;

Negative social-comparative feedback group (NF): received **negative** social-comparative feedback following both the key-pressing and suturing tasks;

Control group (CF): received **no** social-comparative feedback following the key-pressing and suturing tasks.

2.3.2 – *Experimental Apparatus And Tasks*

Key-Pressing Task

The computer key-pressing task was identical to the one used by Eliasz (2012) for testing motor learning paradigms in non-medical university students. The key-pressing portion of the experiment required medical trainees to be seated in front of a 16" wide computer screen (LG model) and a modified keyboard (Microsoft model). The modified keyboard was in line with the trainee's non-dominant hand. All keys on the numeric keypad were removed, with the exception of the keys corresponding to '2', '4', '6' and '8', which were used as the input device. These four keys were each covered with a white faceplate and labeled with down, left, right or up black arrows, respectively. The software tool E-prime, version 2.0 (Psychological Software Tools, PA), was used to program the instructions and task, as well as record the dependent measures of interest (movement time (MT) and errors).

The key-pressing task required all trainees to learn several spatially-unique computer sequences with their non-dominant index finger. Each pattern consisted of five correct key-press steps that the trainee self-discovered. During each trial, a 3x3 grid was presented on the computer screen with the starting position of a coloured square filled in among the rest of the black squares. The trainee's task was to press the appropriate arrow key to virtually move the coloured square to the correct next location in the sequence. Pressing the correct key advanced the coloured square to the new location on the grid (the previous square turned black, like all the other grid squares). If an incorrect key was pressed, the coloured square remained in the same location. The same process occurred for the rest of the sequence until all five correct key-press steps were discovered. The final coloured square in a sequence was marked with the word 'end' to indicate pattern completion. The trainee's goal was to always complete each sequence (i.e., trial) as quickly and accurately as possible.

Suturing Task

The suturing portion of the experiment was completed in a simulated operating environment (suturing was chosen to represent a more training-relevant task). The trainees were all gowned and gloved before being seated at a table covered in blue draping, which contained an artificial skin pad (TruSkin Suture Skin, Pocket Nurse Pittsburgh PA) with a simulated laceration and appropriate instruments (needle driver, scissors, forceps, and silk suture). The blue operating drape had visual markers outlined for tool and hand placement. The suturing task required trainees to watch expert training videos to learn how to perform three stereotyped surgical techniques (i.e., simple interrupted suture, horizontal mattress suture and corner stitch). Each training video was watched once uninterrupted and in the absence of any movements. Following video observation for the simple interrupted and horizontal mattress sutures, trainees were allocated a specified amount of time to practice each suturing technique. Practice time was self-regulated, which meant that trainees could choose whether or not they watched the video (or parts) again while they practiced the procedure.

Suturing performance was captured for specified trials using the Imperial College Surgical Assessment Device (ICSAD; Imperial College, UK) and video recording. The ICSAD tool captured motion data through sensors that were attached to the dorsum of each gloved hand using surgical tape before being secured with wristbands. The specified suturing trials were also filmed using two separate high-definition Panasonic 16GB HC-V100M camcorders, which were each secured on a tripod. One camera was positioned to capture an overall view of the trainee's hands while they were performing the technique (i.e., far view), while the other camera was positioned to provide a close-up view of the laceration (i.e., near view). For all of the recorded trials, the trainee's task was to perform each suturing technique quickly and accurately at the sound of a bell. The bell was also used to sync multiple camera views with the motion analysis system.

2.3.3 – *Experimental Protocol*

Trainees completed two testing sessions that were approximately 24 hours apart. During the first session all trainees performed a key-pressing familiarization test, a key-pressing acquisition session and a key-pressing immediate retention test, followed by a surgical skill acquisition session of two surgical techniques (i.e., simple interrupted suture and horizontal mattress suture). During the second session (~ 24 hours later) all trainees completed a pattern recall test, a key-pressing delayed retention test, a horizontal mattress delayed retention test and a surgical technique transfer test (i.e., corner stitch suture). Figure 2.1 illustrates a schematic of the experimental design. Prior to debriefing and re-consenting to the experiment, trainees were led to believe that the experimenters were interested in examining the influence of observational practice on the acquisition of technical skills and that the computer key-pressing portion of the experiment was assessing their working memory.

<u>Session 1</u>

The key-pressing portion of the experiment was based upon the previous work and methodology used by Eliasz (2012). Trainees were given three practice trials of a unique key-press pattern to orient them to the task. After these practice trials were completed, trainees were asked to record their baseline task-specific self-efficacy for the upcoming pattern on a scale of 0% (no confidence) to 100% (complete confidence). For all of the key-pressing tasks, trainees were provided with the same goal of completing each key-press trial quickly and accurately using only their non-dominant index finger. To ensure that only the index finger was being used, trainees held a small rolled piece of high-density foam in their non-dominant hand (Figure 2.3). The first experimental task required all trainees to complete the key-pressing familiarization test where they were instructed to try to learn one key-press pattern over the course of 16 trials (see Figure 2.2 A – the purple pattern). This test was completed to assess baseline key-pressing performance. Immediately following the completion of this test, trainees in the two feedback groups were shown a fabricated performance summary on the computer screen to indicate how they had performed the key-pressing task relative to others. More specifically, trainees in the PF group were shown fabricated information to inform them that, "based on other people who have completed this test, your predicted capability to successfully learn the upcoming patterns is: 84%" (or a similar number to minimize experimental contamination) (Figure 2.4 A). Those in the NF group were informed that based on their test performance they were predicted to be 16% capable to successfully learn the upcoming patterns (or a similar number to minimize experimental contamination) (Figure 2.4 B) and those in the CF group were not provided with any social-comparative feedback. All trainees were asked to record their task-specific self-efficacy (for the upcoming acquisition patterns) on a scale of 0% (no confidence) to 100% (complete confidence). This self-efficacy measure also served as a manipulation check since it was recorded immediately following the initial feedback manipulation.

During the acquisition phase, trainees were required to learn four different computer key-press patterns (Figure 2.2 B illustrates the five correct key-press steps for the blue, red, green and orange acquisition patterns). Trainees practiced each colour pattern 40 times for a total of 160 acquisition trials. Prior to each acquisition trial, trainees were provided with their goal time (i.e., their personal best MT in ms for a specified pattern) and following each trial, they were given their actual MT feedback. The task goal during the acquisition phase was pattern-specific in that trainees were required to always try and beat their personal best MT for each pattern. If the task goal was achieved (i.e., a 'win') then this new MT became the personal best time for that pattern and the trainee was rewarded with a switch to a different pattern on the next trial; failure to beat their best MT (i.e., a 'loss') resulted in immediate repetition of the same pattern. Therefore, the trial order (task-switching/‘winning’) was dependent upon the trainee’s performance. During the acquisition phase, those assigned to the feedback conditions (i.e., PF and NF groups) were presented with fabricated performance summary graphs that indicated how they were performing relative to the (hypothetical) group average. The fabricated cumulative performance graph was presented every 38 trials during the 160-trial acquisition phase (i.e., after the 38th, 76th, 114th, 152nd trial). Each of the four fabricated graphs illustrated a ‘learning score %’ as a function of performance time. A dark grey bar was used to illustrate the trainee’s performance after ‘x’ amount of trials, and a dotted red line was used to indicate the hypothetical group’s performance after the same amount of trials. To enhance realism, the group average (red dotted line) was set at progressive 'learning score %' increments of 40%, 65%, 77% and 81%. The PF group was shown fabricated performance summaries indicating that they were always performing and learning the key-press patterns better than their peers. Their fabricated performance as indicated by a grey bar was calculated and visually represented as 20% above the group learning score average (indicated by the dotted red line) (see Figure 2.5 A for a PF example). The NF group was shown the opposite; their fabricated performance summary (grey bar) was calculated and visually represented as 20% below the group learning score average (indicated by the dotted red line) (see Figure 2.5 B for a NF example). Trainees in the CF group did not receive any social-comparative feedback.

Following the key-pressing acquisition phase, all trainees completed a spatially-interfering task[5] where they watched two surgical training videos (an introductory video on suturing and tool use, and a training video on the first stereotyped surgical technique – the simple interrupted suture) before completing the key-pressing immediate retention test (10-minute retention). This test consisted of 16 total trials (four trials of each pattern) presented in a random order without any specific goal information (i.e., their personal best MT) or performance feedback (i.e., actual MT). However, trainees were again encouraged to complete each trial as fast and accurate as possible using only their non-dominant index finger.

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[5] Participants completed a Sudoku puzzle as the spatial interference task in the Eliasz (2012) study.

After completing the key-pressing portion of the experiment, trainees were gowned, gloved and seated in front of an artificial skin pad (TruSkin Suture Skin, Pocket Nurse Pittsburgh PA) containing a simulated laceration (Figure 2.6 A). Appropriate instruments (needle driver, scissors, forceps, and silk suture) were placed on top of blue surgical draping (Figure 2.6 B and C). To maximize consistency during all trials, the draping had visual outline markers for tool and hand placement. Imperial College Surgical Assessment Device (ICSAD; Imperial College, UK) was used as a validated measure of hand motion data. Sensors were attached to the dorsal surface of each gloved hand using surgical tape before being secured with wristbands to track the trainee's hand position during the suturing techniques (Figure 2.8 A and B). The suturing portion of the experiment required all trainees to watch the same training videos (same model) and perform two stereotyped surgical techniques (see Figure 2.7 A and B). Prior to practicing the first suturing task (simple interrupted suture) trainees provided a rating of their self-efficacy to perform this specific suturing technique. A total time of 15 $\pm$ 2 minutes was allocated for practicing the simple interrupted suture (Figure 2.7 A). During this time trainees were able to self-regulate how they practiced the simple interrupted suture. For example, trainees could choose to watch the entire video or portions of it while simultaneously practicing the technique or they could choose not re-watch the video (see the bottom of Table 2.2 for specific details). Following practice, video and ICSAD were collected for two separate performance trials of this technique. For each trial, trainees were instructed to place their hands on top of the surgical draping outline markers and at the sound of a bell, quickly and accurately, perform a simple interrupted suture within the laceration (Figure 2.7 A). Following the completion of two trials, trainees were asked to use the modified National Aeronautics and Space Administration-Task Load Index (NASA-TLX) questionnaire to rate their filmed simple interrupted suture performance under the following categories: mental demand, effort, performance and frustration. Trainees were also shown two validated technical skill assessment tools (a suture-specific Global Rating Scale and a Checklist) as examples of how an expert would score their performance.

The trainees in the feedback conditions were led to believe that an expert rater was immediately scoring their filmed performance in another room but instead they were provided with manipulated social-comparative feedback – regardless of actual performance. More specifically, the trainees receiving positive or negative social-comparative feedback were shown performance summaries (scored by an 'expert' rater) indicating that they were performing either better or worse than their peers (Figure 2.9 A and B, respectively). Trainees in the CF group did not receive any social-comparative feedback; however, they were led to believe that an expert rater would also score their filmed performance.

Trainees then watched the second surgical technique instructional video (i.e., horizontal mattress suture) and rated their self-efficacy for performing this technique. They were then required to perform, quickly and accurately, two separate filmed trials (video and ICSAD) of the horizontal mattress suture before receiving 10 $\pm$ 2 minutes to practice the new technique (Figure 2.7 B). Trainees were again able to self-regulate how they practiced the suture. Following practice, two additional trials of the horizontal mattress suture, performed quickly and accurately, were recorded (video and ICSAD). Trainees were then asked to use the modified NASA-TLX to rate their filmed horizontal mattress performance. After completing the suturing acquisition session, those in the two feedback groups were again presented with fabricated feedback (as scored by an ‘expert’ rater and congruent to initial group assignment), regardless of actual performance (Figure 2.9 A and B). To minimize potential study contamination, the two performance summary scores given to the trainees in the feedback groups during the surgical acquisition session were not identical but averaged to 14, above or below the group average (e.g., the first feedback summary indicated a performance score of 13 relative to the average whereas the second showed a performance score of 15 relative to the average for an average performance rating of 14 relative to the average).

Session 2

Trainees arrived back to the testing space approximately 24 hours later, where they were asked to first report a self-efficacy rating for performing the four key-press patterns from the previous session before completing an uncued pattern recall test (untimed pencil-and-paper test) for each separate pattern. Trainees then completed the delayed retention test (24-hour retention) with their non-dominant index finger, which was identical to the immediate retention test completed the day before.

Following the key-pressing retention tests, trainees were gowned, gloved and seated in front of an artificial skin pad containing a simulated laceration and asked to report their self-efficacy for performing the horizontal mattress technique from the previous session. Trainees then performed two separate trials of the horizontal mattress suture from the previous session (video and ICSAD). They used the NASA-TLX to rate their filmed horizontal mattress performance. Following the suturing retention test, trainees watched the corner stitch instructional video (also named the half-buried horizontal mattress suture) and rated their self-efficacy prior to performing one trial[6] (video and ICSAD) of this new suturing technique as a transfer test (Figure 2.7 C). They used the NASA-TLX to rate their filmed corner stitch performance. At the end of this session trainees reported any techniques they used to help them perform and learn the suturing tasks. A manipulation check was also completed[7] to ensure that trainees believed the fabricated feedback from the previous session. Trainees were then debriefed[8] on the true nature of the experiment, asked to re-consent to the experimental protocol and also provided with the option to receive their actual performance scores post-data collection.

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[6] Since this was a transfer test, trainees were not provided any practice time for the corner stitch suture technique.

[7] For the manipulation check trainees were asked 'how do you feel you performed during your last session'.

[8] The debriefing session ensured that trainees understood that the feedback they had received during the experiment was entirely manipulated by the experimenters and did not at all reflect their actual performance and ability to learn both the key-pressing and suturing tasks.

2.3.4 – *Outcome Measures*

Psychological Measures

A baseline measure of motivation was captured using a validated 16 item 7-point Likert state motivation scale (Situational Motivation Scale, SIMS)[9] (Guay et al., 2000) across four independent constructs including intrinsic motivation, identified regulation, external regulation and amotivation. A validated one item 5-point Likert scale captured a baseline trait measure of global self-esteem (Single-Item Self-Esteem Scale, SISE) (Robins et al., 2001). Internal consistency for each subscale of SIMS was as follows: intrinsic motivation Cronbach's $\alpha = .77$, identified regulation Cronbach's $\alpha = .30$, external regulation Cronbach's $\alpha = .79$, amotivation Cronbach's $\alpha = .75$. According to Nunnally and Bernstein's guidelines (1994), internal consistency for all subscales except one (identified regulation) is considered to be acceptable. Since SIMS is a validated scale and we wanted to ensure that the results could be compared against other studies using the same scale, items for the identified regulation subscale were not deleted in order to increase consistency.

Self-reported self-efficacy was measured at several time points prior to the key-pressing and suturing tasks across both testing sessions. The scales measured task-specific self-efficacy from 0-100% and were developed as per Bandura's recommendations (Bandura, 2006).

[9] The SIMS scale only measured state motivation related to the suturing task.

Self-reported mental demand, effort, performance and frustration were subscales that were used from the National Aeronautics and Space Administration-Task Load Index (NASA-TLX) questionnaire (Hart & Staveland, 1988). The NASA-TLX measures perceived workload using the combination of six weighted subscales on a 20-point interval scale. However, only four of the six subscales were relevant to the task and therefore they were never combined and weighted for a total workload score. Instead each subscale was recorded on a modified scale of 0-100% following *only* the suturing tasks during both testing sessions. Subscales were converted to 0-100% in order to be consistent with the self-efficacy scales and avoid participant confusion.

<u>Behavioural Measures</u>

Key-press errors and MT were extracted from a custom-written software program (E-prime version 2.0, Psychological Software Tools, PA) (Eliasz, 2012; Lee et al., 2016) to assess key-pressing performance during both testing sessions. MT was measured as the time in ms lapsed from the first to the last key-press for each trial. Key-press errors were measured as the total number of incorrect key-presses made during each trial.

At the beginning of the second session, one of the retention tests consisted of an uncued pattern recall test. There was no time limit imposed during this test. Trainees were provided with a paper illustration of four blank 3x3 grids, resembling the grid from the computer screen, and instructed to draw the starting square and subsequent five-step path for each pattern. Following data collection, the experimenter scored each incorrect response on the grid as a recall error, for a potential maximum of 20 recall errors across all four colour patterns.

Suturing performance (i.e., hand motion efficiency) during both testing sessions was assessed by two measures: total trial time (s) and number of hand movements. These variables were extracted from the Imperial College Surgical Assessment Device (ICSAD; Imperial College, UK), which incorporates an electromagnetic motion tracking system (Polhemus, Patriot, VT) (Figure 2.8 A and B) to capture hand motion data through sensors placed on the dorsum of each hand. These objective metrics have been validated against the gold standard of technical skill assessment (i.e., expert judgments on the Global Rating Scale and Checklist) (Datta, Mackay, Mandalia, & Darzi, 2001; Datta, Mandalia, Mackay, Chang, Cheshire, & Darzi, 2002; Dumestre, Yeung, & Temple-Oberle, 2014; Jowett, Leblanc, Xeroulis, MacRae, & Dubrowski, 2007). Superior suturing performance (experts compared to novices) is depicted by fewer hand movements and less time to completion (Dumestre et al., 2014).

2.3.5 – *Data Analyses*

SPSS statistical software (SPSS version 21, Chicago, Illinois) was used to conduct analyses and all significant differences were determined by *p* values less than 0.05. The Greenhouse-Geisser correction was applied when sphericity was violated. Estimates of effect size were reported using Partial Eta Squared (η_p^2) for all significant findings. In one-way ANOVAs, Partial Eta Squared and Eta Squared (η^2) will be equal.

Demographic Measures

Demographic baseline measures of interest included the SIMS (intrinsic motivation, identified regulation, external regulation and amotivation) and the SISE scale, which were each analyzed using separate one-way ANOVAs. Although these measures are ordinal in nature, Likert scales have been analyzed using parametrical statistics (Carifio & Perla, 2008; Gonzalez, Metzler, & Newton, 2011; Norman, 2010).

Key-Pressing Task

For both key-press errors and MT, trials of 16 (four of each colour) were aggregated together and represented as a block of trials (10 blocks for acquisition and single blocks for the familiarization task as well as the immediate and delayed retention tests).

The key-press familiarization data for key-press errors and MT were each analyzed using separate one-way ANOVAs.

The key-press acquisition data for key-press errors and MT were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 10 (block: each block of 16 trials with 4 trials of each pattern) mixed ANOVA with repeated measures on the last factor.

Since the acquisition phase employed a task-switching algorithm based upon a trainee's performance, the number of task-switches (per block of 40 trials) was recorded. The key-press acquisition data for task-switches were analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 4 (block: each block of 40 trials with 10 trials of each pattern) mixed ANOVA with repeated measures on the last factor.

The key-press retention data for key-press errors and MT were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 3 (test: end of acquisition, immediate retention, delayed retention) mixed ANOVA with repeated measures on the last factor.

The baseline key-press self-efficacy data were analyzed using a one-way ANOVA. The acquisition and retention key-press self-efficacy data were analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 2 (post-manipulation test time: pre-acquisition, pre-delayed retention) mixed ANOVA with repeated measures on the last factor.

The pattern recall test data were analyzed using a one-way ANOVA.

<u>Suturing Task</u>

For both time and hand movements, a total of nine trials were recorded for each trainee: two trials were recorded for the simple interrupted suture; two trials each for the pre-practice, post-practice and retention of the horizontal mattress suture; and one trial for the corner stitch. Each trial mean for the hand movements variable included the sum of the left and right hand movements[10]. Also, in order to discriminate insignificant from significant hand movements and remove background noise (measurement error and hand tremor), a recommended velocity threshold value of 7.5 mm/sec and a Gaussian filter using a width of 16 for

[10] Since the hands were completing different actions during the suturing tasks, the left and right hand movements were not averaged.

surgical tasks was applied (Brydges, Classen, Larmer, Xeroulis, & Dubrowski, 2006; Dosis, 2005).

The simple interrupted suture data and the corner stitch suture data for the ICSAD measures of interest (time, number of hand movements) were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last factor.

The horizontal mattress suture data for the ICSAD measures of interest (time, number of hand movements) were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 3 (test: pre-practice, post-practice, retention) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last two factors.

The suturing self-efficacy data for the simple interrupted suture and corner stitch suture (transfer test) were each analyzed using one-way ANOVAs. The acquisition and retention suturing self-efficacy data for the horizontal mattress technique were analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 2 (test time: pre-practice, pre-delayed retention) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last two factors.

The simple interrupted suture and corner stitch suture data for the NASA-TLX measures of interest (mental demand, effort, performance, frustration) were each analyzed using one-way ANOVAs. The horizontal mattress suture data for the NASA-TLX measures of interest (mental demand, effort, performance, frustration) were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 2 (test: acquisition, delayed retention) mixed ANOVA with repeated measures on the last factor.

2.4 – RESULTS[11]

Demographic Measures

Descriptive statistics (shown in Table 2.1) suggest that the trainees recruited for this study represent a subset of highly-motivated participants and is in line with previous research. Analyses for each subscale of the SIMS (intrinsic motivation, identified regulation, external regulation and amotivation) and for the SISE scale revealed no significant baseline group differences for both (state) motivation and (trait) self-esteem.

Key-Pressing Task

Analysis of the familiarization key-press data (prior to any feedback manipulations) for both key-press errors and MT revealed no group differences.

Analysis of both the key-press errors and MT acquisition data revealed a significant main effect for block, $F(2.03, 54.79) = 123.52$, $p < .001$, $\eta_p^2 = .821$ and $F(1.94, 52.46) = 160.12$, $p < .001$, $\eta_p^2 = .856$, showing that key-press patterns were performed significantly more accurately and quickly over acquisition blocks (particularly towards the beginning of practice). Based on previous research (Eliasz, 2012), we expected that the delivery of social-comparative feedback would modify performance variables during acquisition (particularly at the

[11] For all effects, associated means and standard deviations are reported in Tables 2.1 and 2.2.

beginning of practice); however, there were no main effects for group found across acquisition blocks for both key-press errors and MT. There were also no group effects found for the first acquisition trial post-feedback manipulation. Analysis of the key-press task-switch data revealed a significant main effect for block, $F(3, 81) = 171.23$, $p < .001$, $\eta_p^2 = .864$, showing that the number of task-switches significantly decreased across acquisition blocks. No group effects were found for the number of task-switches during acquisition, which meant that there were no significant differences related to goal attainment. No other effects were found.

Analysis of the key-press error retention data (Figure 2.10) revealed a significant interaction between group and test, $F(4, 54) = 2.55$, $p = .049$, $\eta_p^2 = .159$. Post-hoc analysis revealed that the NF group made significantly more errors than the PF and CF groups on the delayed retention test (M = 9.8 errors compared to M = 5.3 errors and M = 3.8 errors), with these errors being significantly greater compared to all errors made at the end of acquisition and on the immediate retention test. There was also a significant main effect for block, $F(2, 54) = 4.34$, $p = .018$, $\eta_p^2 = .821$, showing that key-press patterns were performed significantly less accurately on the delayed retention test compared to the other testing points. There was no main effect found for group.

Analysis of the key-press MT retention data (Figure 2.11) revealed a significant main effect for test, $F(1.32, 35.54) = 7.22$, $p = .006$, $\eta_p^2 = .211$ with MT significantly increasing across testing blocks (end of acquisition M = 704 ms, immediate retention M = 766 ms, delayed retention M = 891 ms). Assumption of homogeneity of variances was violated (i.e., Levene's test) on the between-subjects factor for the MT retention data analysis. High variability was predominantly present in the PF group (Zar, 1996). To further investigate this unexpected result, a 3 (social-comparative feedback group: Positive, Negative, Control) x 3 (test: end of acquisition, immediate retention, delayed retention) mixed ANOVA with repeated measures on the last factor was computed on only the standard deviation values. This analysis revealed a main effect for group, $F(2, 27) = 3.49$, $p = .045$, $\eta_p^2 = .206$. Post-hoc analysis revealed that PF group had significantly greater standard deviation values (M = 496.1 SD) compared to CF group (M = 171.6 SD). No interaction and no main effect for block were found.

The key-press recall error data (Figure 2.13) violated the assumption of homogeneity of variances (Levene's test). However, the ANOVA is fairly robust (in other words, insensitive) with respect to violations of the assumptions (e.g., violations against equal variance assumption) (Zar, 1996), particularly when sample sizes are equal as in the present case (Glass & Stanley, 1970). The one-way ANOVA for pattern recall errors revealed a significant main effect for group, $F(2, 27) = 3.37$, $p = .049$, $\eta_p^2 = .200$. Trainees in both the PF and NF groups produced significantly more errors (M = 3.9 errors and M = 3.4 errors) compared to the CF group (M = 0.5 errors) on the uncued pattern recall test during the second session. The unequal variance F-test (i.e., Welch's F test) was also computed for the pattern recall error data (parametric method for comparing independent samples). The obtained Welch's adjusted F ratio (5.93) for a one-way ANOVA was still significant at the .05 alpha level, Welch's $F(2, 13.86) = 5.93$, $p = .014$. The Games-Howell multiple comparison method (post-hoc analysis used for Welch's ANOVA) revealed that only the NF group produced significantly more errors compared to the CF group. Both tests (ANOVA and Welch's F test) report similar results for the primary effects, which adds further support for the robustness of the ANOVA however; interpretation will be based on the original post-hoc comparison procedures to remain consistent throughout.

Analysis of the baseline key-press self-efficacy data (Figure 2.12) revealed no significant group differences. Following the feedback manipulation (pre-practice to pre-delayed retention), the key-pressing self-efficacy ratings revealed a significant main effect for group, $F(2, 27) = 3.56$, $p = .042$, $\eta_p^2 = .209$ (Figure 2.12). Post-hoc analysis revealed that those in the NF reported significantly lower self-efficacy ratings (M = 70%) compared to the other groups (M = 83% for both PF and CF). A significant main effect for time $F(1, 27) = 21.54$, $p < .001$, $\eta_p^2 = .444$, revealed that self-efficacy ratings were reported as higher before acquisition than they were before the delayed retention test (M = 86% compared to M = 71%). There was no interaction.

Suturing Task

Analysis of the hand movements data for the simple interrupted suture (Figure 2.14) revealed a significant main effect for trial, $F(1, 27) = 17.99$, $p < .001$, $\eta_p^2 = .400$, where the second trial was generally performed with fewer movements than the first (M = 131 compared to M = 153 hand movements). No interaction and no main effect for group were found.

Analysis of the hand movements retention data for the horizontal mattress suture (Figure 2.14) revealed a significant main effect for trial, $F(1, 27) = 44.54$, $p < .001$, $\eta_p^2 = .623$, where trainees produced significantly fewer hand movements on the second trial compared to the first (M = 173 compared to M = 192 hand movements). There was also a significant main effect for test, $F(2, 54) = 33.66$, $p < .001$, $\eta_p^2 = .555$, where trainees made significantly more hand movements on their first two trials of the horizontal mattress suture (M = 206) compared to the end of acquisition (M = 177) and delayed retention test (M = 165). No interactions and no main effect for group were found.

Analysis of the hand movements transfer data for the corner stitch suture (Figure 2.14) revealed a significance main effect for group, $F(2, 27) = 4.21$, $p = .026$, $\eta_p^2 = .238$ with the NF group requiring more hand movements (M = 188 hand movements) to complete the task compared to the PF and CF groups (M = 161 and M = 155 hand movements, respectively).

Analysis of the total task time for the simple interrupted suture (Figure 2.15) revealed a significant main effect for trial, $F(1, 27) = 36.56$, $p < .001$, $\eta_p^2 = .575$, where trainees took significantly less time to complete the second trial compared to the first (M = 146 s compared to M = 181 s). No interaction and no main effect for group were found.

Analysis of the total task time retention data for the horizontal mattress suture (Figure 2.15) revealed a significant interaction for trial and test, $F(2, 54) = 7.29$, $p = .002$, $\eta_p^2 = .213$. Post-hoc analysis revealed that trainees were quicker on the second trial compared to the first (M = 190 s to 217 s) and across tests (M = 181 s on the first test compared to the second, M = 195 s, and third, M = 235 s). No interactions and no main effect for group were found.

Analysis of the total task time transfer data for the corner stitch suture task (Figure 2.15) revealed a significant main effect for group, $F(2, 27) = 3.92$, $p = .032$, $\eta_p^2 = .225$, with the NF group taking significantly longer (M = 231 s) to complete the task in comparison to the PF and CF groups (M = 188 s and M = 192 s, respectively).

Analysis of the suturing self-efficacy rating data for the simple interrupted suture (Figure 2.16) revealed no main effect for group. There were also no main effects for group and test or interaction found for the horizontal mattress self-efficacy retention data (Figure 2.16). Analysis of the self-efficacy rating transfer data for the corner stitch suture task (Figure 2.16) revealed an effect approaching conventional levels of significance for the main effect of group, $F(2, 27) = 2.90$, $p = .072$, $\eta_p^2 = .177$, with the NF group generally reporting lower self-efficacy (M = 56%) to complete the corner stitch suture compared to the PF and CF groups (M = 67% and M = 75%, respectively).

Analysis of the suturing frustration rating data for the simple interrupted suture (Figure 2.17) revealed a significant main effect for group, $F(2, 27) = 4.61$, *p* = .019, η_p^2 = .255. Post-hoc analysis revealed that the CF group rated their frustration significantly lower for the simple interrupted suture (M = 26%) compared to the PF and NF groups (M = 49% and M = 44%, respectively).

Analysis of the suturing frustration rating retention data for the horizontal mattress suture (Figure 2.17) revealed a significant main effect for test, *F*(1, 27) = 10.04, *p* = .004, η_p^2 = .271. Post-hoc analysis revealed that the trainees rated their frustration significantly lower for the second horizontal mattress suture (M = 32%) compared to the first (M = 41%). There was no main effect found for group or interaction.

Analysis of the suturing frustration rating transfer data for the corner stitch suture (Figure 2.17) revealed a significant main effect for group, *F*(2, 27) = 3.79, *p* = .035, η_p^2 = .219. Post-hoc analysis revealed that the NF group rated their frustration significantly greater for the corner stitch suture (M = 53%) compared to the CF group (M = 33%).

Analysis of the suturing mental demand rating data for the simple interrupted suture revealed no main effect for group. Analysis of the mental demand rating for the horizontal mattress suture retention data revealed a significant main effect for test, *F*(1, 27) = 18.59, $p < .001$, η_p^2 = .408. Post-hoc analysis revealed that trainees rated their mental demand significantly lower for the second horizontal mattress suture (M = 59%) compared to the first (M = 71%). There was no main effect found for group or interaction. Analysis of the suturing mental demand rating transfer data for the corner stitch suture revealed no main effect for group.

Analysis of the suturing effort rating data for the simple interrupted suture revealed no main effect for group. Analysis of the suturing effort rating for the horizontal mattress suture retention data revealed a significant main effect for test, $F(1, 27) = 29.63$, $p < .001$, $\eta_p^2 = .523$. Post-hoc analysis revealed that trainees rated their effort significantly lower for the second horizontal mattress suture (M = 57%) compared to the first (M = 70%). Analysis of the suturing effort rating transfer data for the corner stitch suture revealed no main effect for group.

There were no main effects or interactions found for the suturing performance ratings across all three suturing techniques (i.e., simple interrupted, horizontal mattress, corner stitch).

Self-Regulatory Techniques During Suturing Practice[12]

The suturing training videos (for both the simple interrupted and horizontal mattress suture) were watched the least by the PF group compared to the NF and CF groups.

The NF group performed significantly fewer simple interrupted sutures during practice than the trainees in the PF and CF groups.

Suturing Learning Strategies

The NF group reported using primarily different strategies *during* suturing to help them perform and learn the suturing techniques compared to both the PF

[12] See Table 2.2 for specific details.

and CF groups, which reported using primarily different strategies *prior* to suturing performance (see Table 2.2 for details).

2.5 – DISCUSSION

Contrary to previous findings (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012 (Experiment 1); Wulf & Lewthwaite, 2016), the results of this study demonstrate that medical trainees, a subset of highly-motivated learners, interpret social-comparative feedback differently than other learners studied in the literature. More specifically, several measures (both psychological and behavioural) in this present study indicate that novice medical trainees receiving positive social-comparative did not display enhanced learning compared to a control condition, whereas those receiving negative social-comparative feedback experienced detriments to their learning process. Interestingly, this pattern of results was present across both tasks (key-pressing and suturing), which suggests that there is something inherently different about how medical trainees (highly-motivated learners) interpret and react to social-comparative feedback that is evident across a broader range of learning experiences.

Our findings in this study contradict the large body of evidence suggesting that different levels of the learning process are facilitated when learners receive information (feedback included) that is positive in nature (Aronson et al., 2002; Avila et al., 2012; Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009;

Dweck, 1999, 2002, 2006; Eliasz, 2012; Hutchinson et al., 2008; Janelle et al., 1997; Janelle et al., 1995; Lee et al., 2016; Lewthwaite et al., 2015; Lewthwaite & Wulf, 2010; Patterson & Carter, 2010; Saemi et al., 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2009; Wulf et al., 2010, 2012). It has proposed that a positive mindset enhances psychological constructs like motivation, which results in altering actual behaviour. However, what has been neglected in these studies is the *motivation at the level of the learner*. Our present study aimed to adjust for this factor by using highly-motivated learners.

In this study, novice medical trainees were representative of highly-motivated learners, both according to the literature (Ferguson et al., 2002; Hutchins, 1964; Kusurkar et al., 2011; Mattick & Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner & Nicholson, 2011) as well as our findings (Table 2.1). The motivation profiles of the medical trainees in this study suggest that they had high self-esteem (trait) in addition to high intrinsic motivation and low extrinsic and amotivation for suturing – meaning that they were motivated for the ‘right reasons’ for the suturing task (state motivation). Unexpectedly, our findings suggest that the type of learner, in this case – highly-motivated, alters the beneficial effects that positive information typically provides.

Positive social-comparative feedback did not facilitate psychological and behavioural outcomes in highly-motivated learners. Our findings provide an indication that receiving positive social-comparative feedback starts to become detrimental towards learning a less relevant task for novice medical trainees. Moreover, novice trainees that were provided with positive social-comparative feedback for a less-relevant task (i.e., computer key-pressing) experienced detriments to their learning process. There was also evidence that there was high variability in how this positive social-comparative feedback was being interpreted by novice medical trainees (on the key-pressing MT variable). The variability in the interpretation could have been due to the high frequency of social-comparative feedback that was being delivered (five instances) on what could have been perceived as a less important task. Interestingly, the positive social-comparative feedback that was delivered during the training-irrelevant task also changed the self-regulatory strategies that were used by trainees for the training-relevant task (i.e., suturing). For example, trainees receiving positive social-comparative feedback on the key-pressing task watched the first suturing video the least and this was prior to any suturing feedback manipulations (i.e., 20% of PF trainees chose to watch the video while they practiced the technique compared to the other two groups: 100% of those in the NF group and 70% of those in the CF group). Following the first suturing feedback manipulation (after the performance of the simple interrupted suture), which essentially confirmed that the PF trainees were still performing above average, did not modify how much the trainees chose to watch the video while practicing the new suturing technique (i.e., 20% of the PF trainees chose to watch the video compared to the other two groups: 100% of those in the NF group and 80% of those in the CF group). Perhaps this initial shift in self-regulatory strategies (in this case, to *not* watch the training video during practice) was due to overconfidence that may have been induced as a result of the key-pressing task, which then carried over to the suturing task. Although there were no group differences found for the suturing acquisition outcomes (e.g., number of sutures that were completed during practice), trainee perceptions may have been modified as a result of the fabricated feedback that they had received during the key-pressing task, which primed them to alter their strategies for an unrelated task (i.e., suturing). This is inline with some of the evidence in the literature suggesting that social-comparative feedback can modify perceptions and not behaviour (Lamarche et al., 2011; Lamarche et al., 2008). However, there can be significant consequences to having an inflated sense of confidence (Baumeister, 1989), and the consequences of overconfidence in settings like heath care could have dangerous and costly implications.

Although we found no *behavioural* carry-over effects (i.e., no group differences on the suturing baseline task following the key-pressing feedback manipulations), we did find behavioural outcome differences in the number of sutures that were completed *prior* to the first suturing feedback manipulation. Specifically, trainees receiving negative social-comparative feedback performed significantly fewer simple interrupted sutures during practice than the trainees in the other two groups. However, this could have been due to the fact that all NF trainees watched the simple interrupted suture video while they practiced the technique. Perhaps the NF trainees threw fewer sutures because they were more careful (and as a result, slower) when practicing the technique or because they were focused on re-watching the video to ensure that they would do better on the suturing task (i.e., not have to again be informed that they were below average compared to their peers). Interestingly, following the first suturing feedback manipulation, all trainees in the NF group still watched the new training video during practice (for the horizontal mattress); however, the amount of horizontal mattress sutures they completed during practice did not differ significantly compared to trainees in the other two groups.

The NF group also experienced psychological and behavioural detriments related to both the key-pressing and suturing task. Specifically, the negative social-comparative feedback during the key-pressing task (*Session 1*) was damaging to self-efficacy ratings for the key-pressing task done the next day (i.e., the NF group reported significantly lower self-efficacy ratings compared to the other two groups). In addition, the NF group also experienced detriments to their delayed key-pressing retention test, where they performed significantly more key-press errors compared to trainees in the other two groups. Remarkably, there were no group differences found for suturing performance on either the simple interrupted suture or the horizontal mattress suture. This finding could have been due to the high amount of reinforcing feedback that had been received (i.e., frequency of seven times), and as a result encouraged NF trainees to become temporarily desensitized to it (e.g., inferred from there being no group differences in self-efficacy ratings for suturing). However, this potential desensitization did dissipate as the NF trainees experienced both suturing performance detriments (i.e., performing significantly slower and with more hand movements compared to the other groups) and significantly greater ratings of frustration for the transfer task (i.e., a new suturing technique – the corner stitch suture).

Interestingly, we also noticed a pattern of attentional shifts with respect to the performance and learning strategies that the NF trainees reported before they were debriefed. For instance, 90% of NF trainees reported that they employed strategies *during* the actual suturing tasks (e.g., step rehearsal while they were performing the technique); whereas, most trainees in the PF and CF groups reported strategies that they employed *prior* to performing the technique (e.g., rehearsing the steps of the suture before performing it). These results suggest that emotional states, which were modified by the negative social-comparative feedback (e.g., frustration ratings), may have caused the reported strategy changes during *Session 2* (and the shift in attention – directing thoughts *during* the suturing task). Research has demonstrated that feedback, in this case negative social-comparative feedback, has the capacity to alter the locus of attention (Kluger & DeNisi, 1996). The psychological effects of negative social-comparative feedback may have influenced learning in such a way that directed the trainee's attention away from the primary task of suturing to instead focus on the emotional aspect of receiving this type of feedback. Research in emotions also supports this suggestion (Brand, Reimer, & Opwis, 2007; Easterbrook, 1959; Ellsworth & Scherer, 2003; Frijda, 1993; Moors, Ellsworth, Scherer, & Frijda, 2013). Furthermore, when working memory becomes occupied with non-relevant information such as thoughts/feelings, attention can be diverted away (decoupled) from the primary task (Smallwood, Fishman, & Schooler, 2007; Smallwood & Schooler, 2006). Future research warrants investigation into how social-comparative feedback alters practice (and particularly learning strategies).

There are several explanations for why negative social-comparative feedback was detrimental to highly-motivated learners like medical trainees in this study. One potential reason could be in line with the cognitive dissonance research (Aronson, 1992; Festinger, 1957; Frey, 1986). For instance, conflicting thoughts/behaviours create a negative psychological state of discomfort that individuals are driven to resolve. Moreover, this line of research suggests that highly-motivated learners experience greater dissonance (discrepancy) when they receive information (for instance, feedback) that misaligns with their own self-perceptions (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Sedikides & Strube, 1997; Steele, 1988). Our findings support these suggestions, as the motivational profiles of the learners in this study were high on both a trait and state level (high levels of motivation, self-esteem and self-efficacy). As a result, the significant misalignment between the fabricated negative social-comparative feedback that was received and the high motivational level of the learner, could have caused an adverse emotional reaction and in turn, a cascade of detrimental consequences.

Our results also suggest that highly-motivated learners can effectively learn different motor tasks in the absence of any feedback (e.g., the performance of the CF group in this study not differing from the PF group). This is somewhat contrary to how the CF group behaved in the previous key-pressing study using non-medical learners (i.e., the CF group did not differ from the NF group) (Eliasz, 2012). Furthermore, the findings of this study provide support that the trainees in this study were highly-motivated and that the CF learners seemed to experience increases to psychological variables such as self-efficacy beliefs just by engaging in practice. The CF group even reported significantly lower frustration levels for performing the initial suturing technique compared to the trainees in the two feedback conditions[13].

The results of this study are particularly important from a theoretical perspective. Specifically, the *individual* in the learning process has been largely overlooked in previous research despite the important role that this may have (i.e., the learner being at the core of the learning process). The findings of this study provide evidence that motivation at the level of the learner cannot be disregarded as high levels modify psychological and behavioural variables in a different manner compared to other types of learners studied in the literature. Otherwise, we face the danger of overgeneralizing phenomena based on replication studies involving different age groups of learners and overlooking different types of learners (i.e., current recommendations being made based on age and not ability)

[13] At that point, the PF group had already received five instances of feedback informing them that compared to their peers they were learning the key-pressing task above average.

(Wulf & Lethwaite, 2016). Furthermore, trait and state motivation are both important variables to consider in the learning context and understanding how *individual difference* constructs interact will provide important information for predicting learning performance.

Despite the novel findings, this study consists of several limitations. We know from the *suturing importance rating* that the medical trainees in this study perceived the suturing task to be of high importance (i.e., based on their suturing importance ratings); however, we failed to collect a task importance measure for the key-pressing task. Although we do not have quantitative evidence to confirm that the key-pressing task was perceived to be less important to medical trainees, we infer this through the lack of behavioural changes occurring during the key-pressing task despite the several feedback manipulations that were implemented. Additionally, the study was advertised as a suturing study and therefore the key-pressing task was not the primary activity that was promoted. Unfortunately, due to methodological constraints, one of the greatest limitations in this study is the potential of task carry-over effects, which we aim to mitigate in the following study (Study 2, Chapter 3). Another limitation of this study is that the frequency of feedback delivery is not realistic of a typical clinical training environment and as a result, the clinical applications are somewhat reduced. The next study will also address this shortcoming.

To our knowledge, this study provides the first demonstration that novice medical trainees, a subset of highly-motivated learners, do not respond to social-comparative feedback in the same manner as other learners do. Our findings suggest that there is a relationship between negative social-comparative feedback and mindset that modifies behavioural and psychological factors in highly-motivated learners (i.e., novice medical trainees learning suturing techniques). Specifically, this study adds to our understanding of how highly-motivated learners, irrespective of the task, interact with and are influenced by social factors inherent in some types of feedback (e.g., social-comparative feedback). The impact of this study is primarily theoretical as it examined extensions of motivational frameworks that have been neglected in different lines of research, particularly in the motor learning domain, with possible direct applications to applied settings like health care.

2.6 – FIGURE AND TABLE APPENDIX

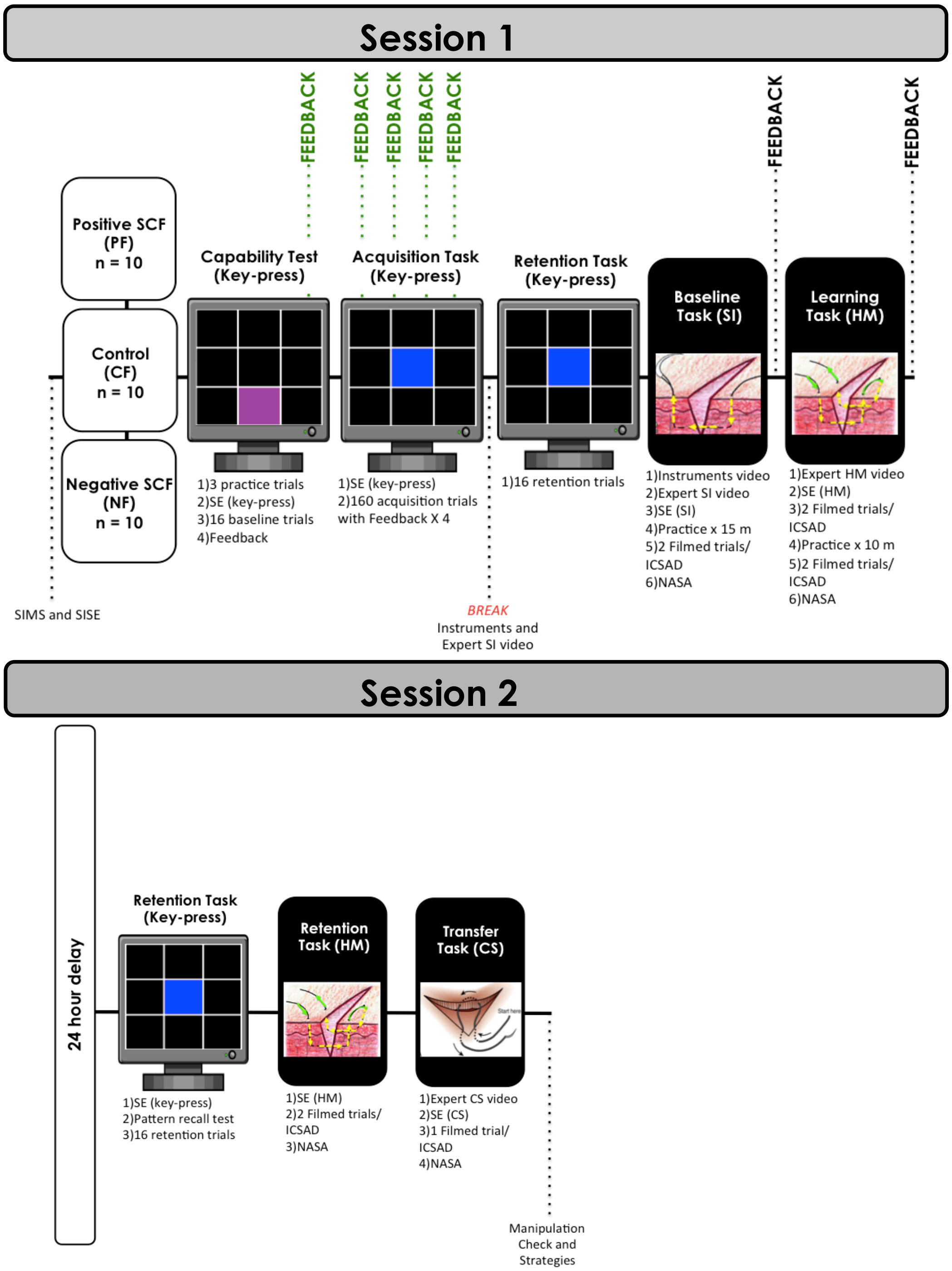

Figure 2.1. Experimental design for Study 1.
Note. SIMS = situational motivational scale; SISE = single-item self-esteem scale; SE = self-efficacy; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index; ICSAD = Imperial College Surgical Assessment Device

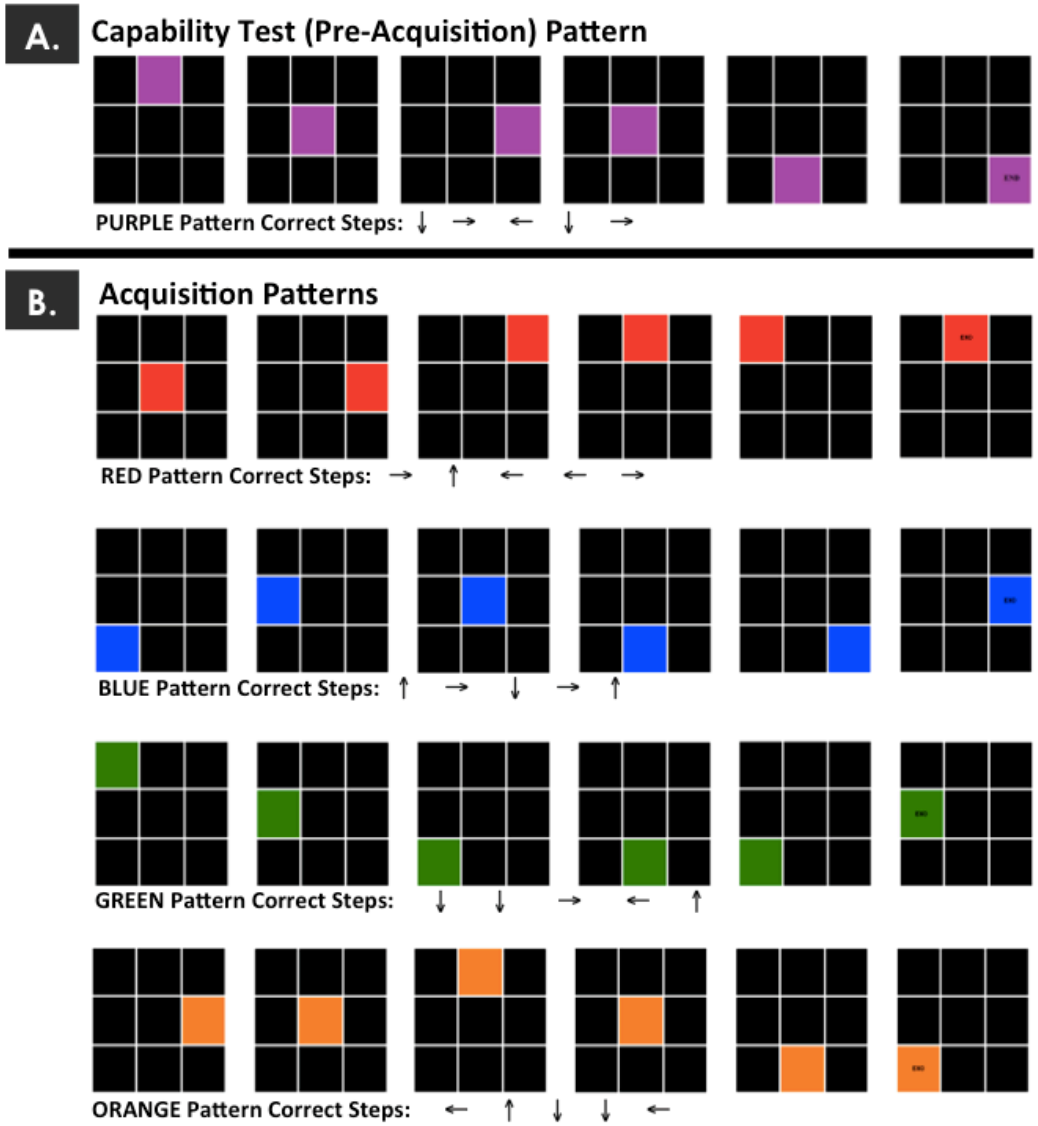

Figure 2.2. A. The correct key-press sequence for the familiarization task pattern (this task was completed pre-acquisition/pre-feedback manipulation); **B.** The correct key-press sequence for each of the four colour acquisition patterns (red, blue, green, orange).

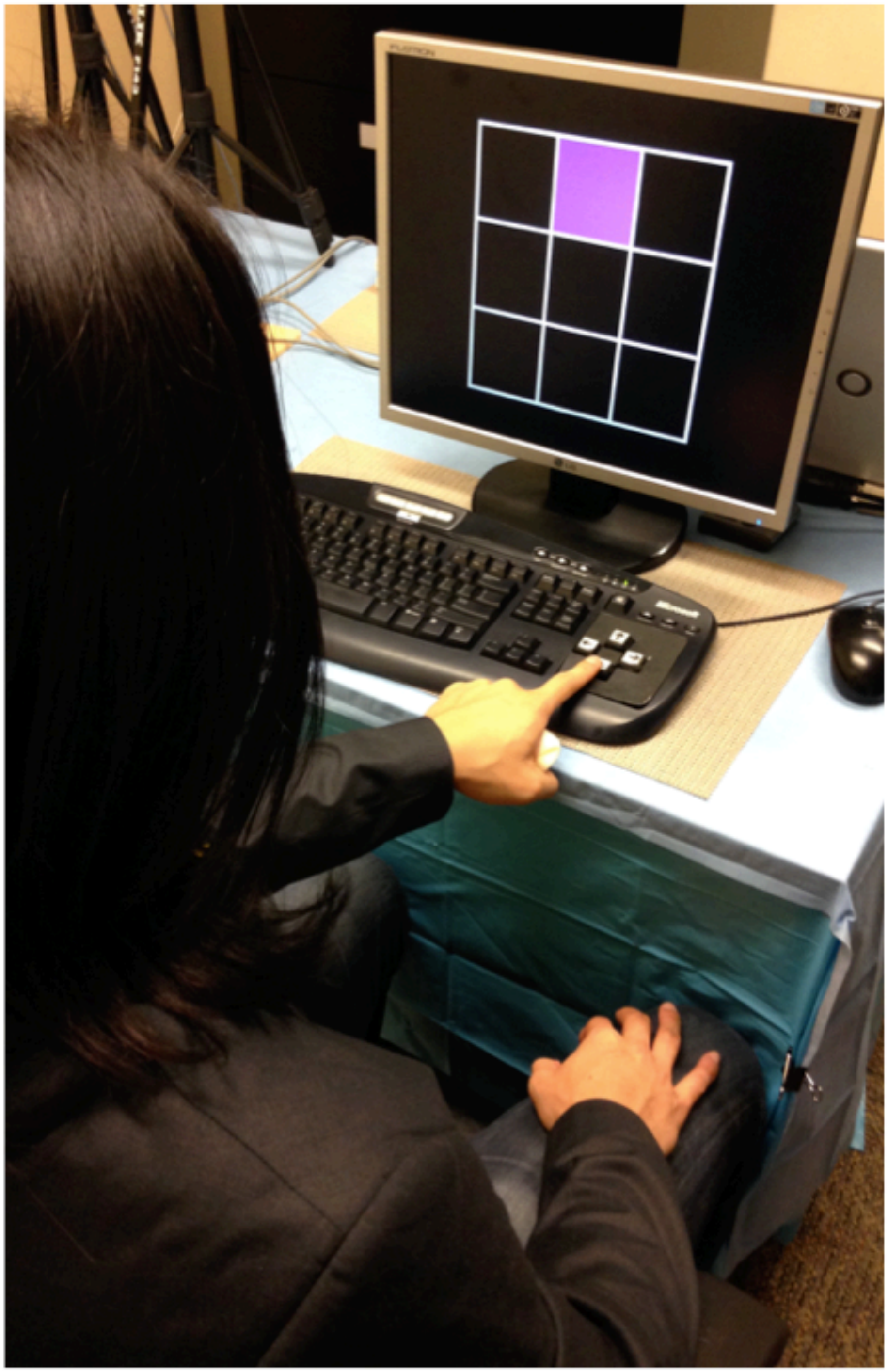

Figure 2.3. Experimental set-up for the key-pressing portion of the study.

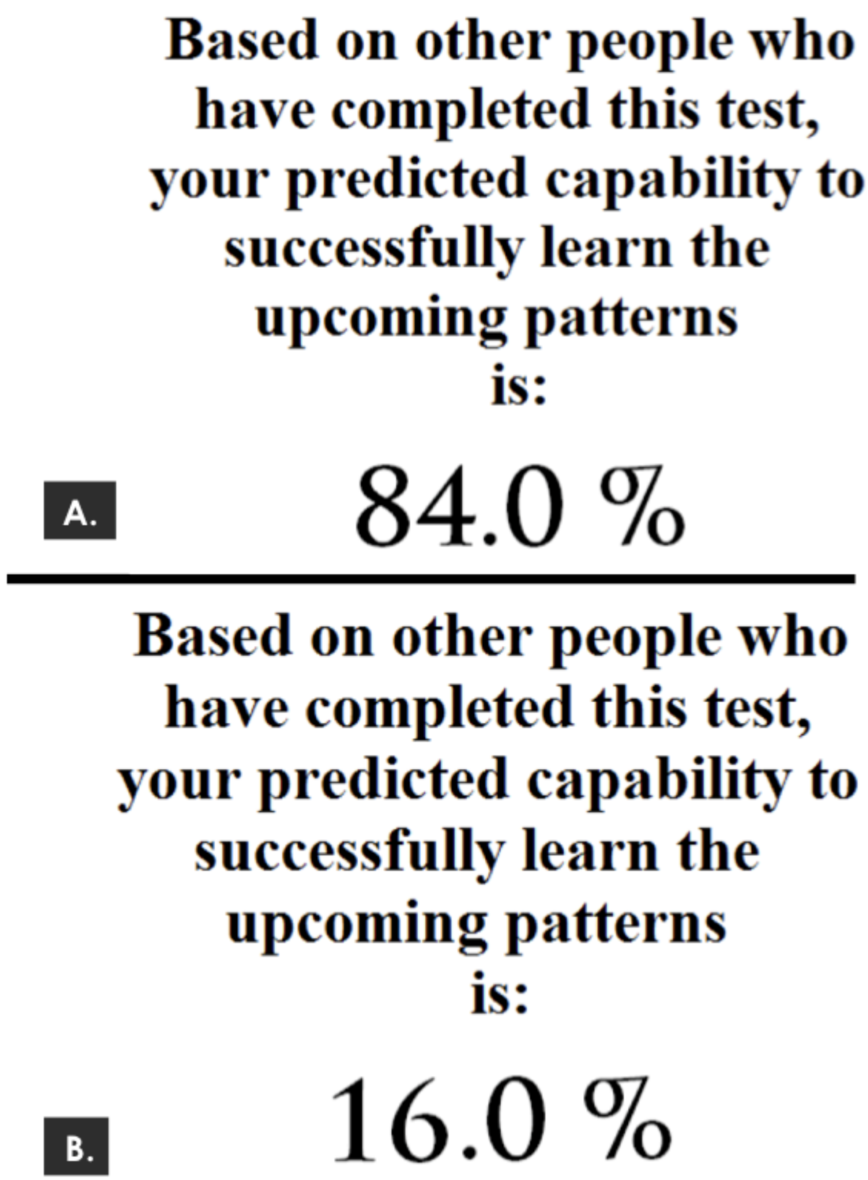

Figure 2.4. An example of the feedback provided to the PF and NF trainees following the familiarization task (but prior to acquisition). **A.** An example of the performance summary provided to the PF trainees pre-acquisition; **B.** An example of the performance summary provided to the NF trainees pre-acquisition.

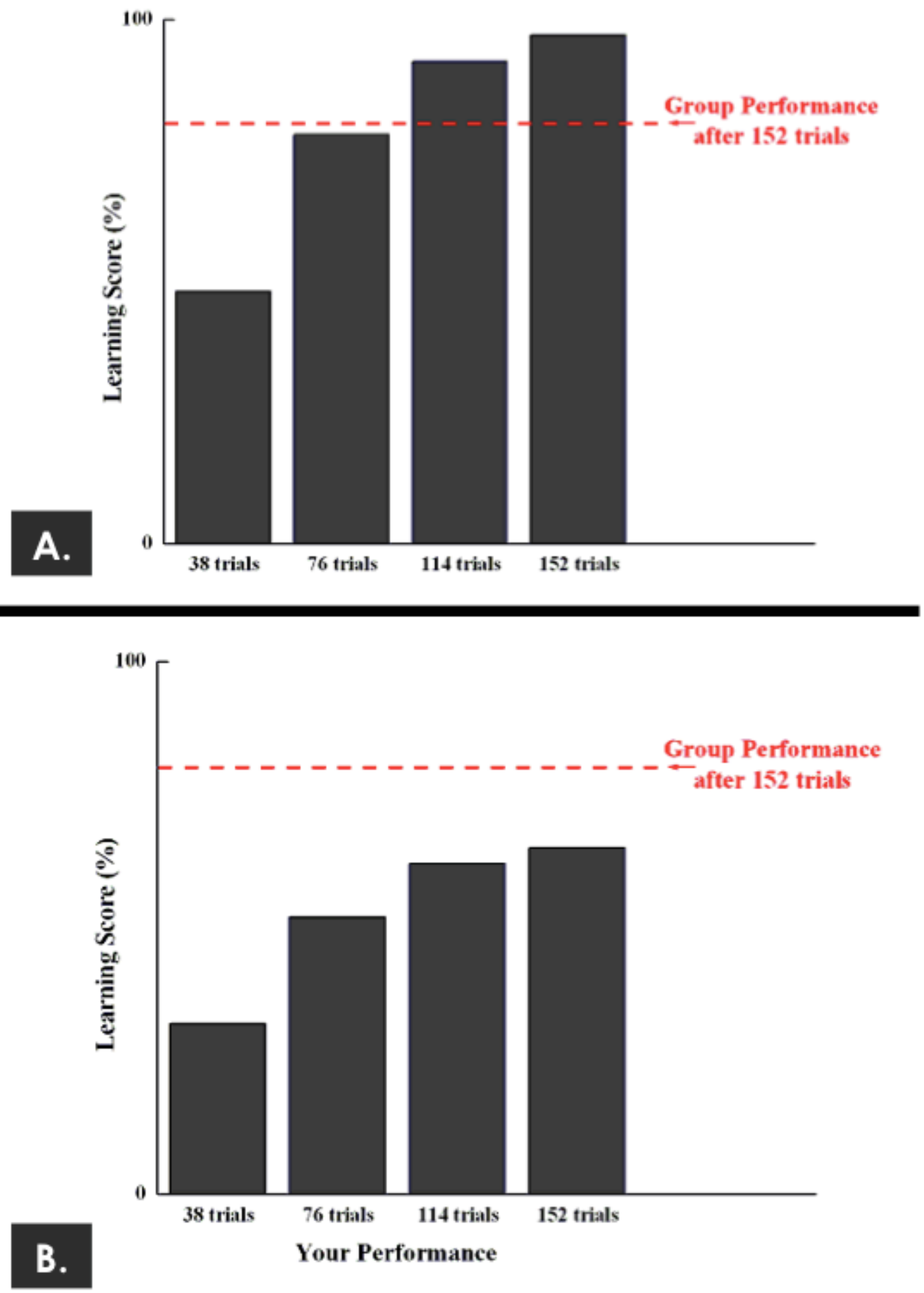

Figure 2.5. An example of the cumulative performance graphs that the PF and NF trainees received during the key-pressing acquisition phase. These performance summaries were displayed after the 38th, 76th, 114th and 152nd trial. The fabricated group performance average was always calculated/shown as 20% below/above the trainee's fabricated performance average.
A. An example of the final performance summary (4th graph) provided to the PF trainees. This (fabricated) bar graph illustrates that the trainee is learning more effectively (higher 'learning score %') than the (fabricated) group; **B.** An example of the final performance summary (4th graph) provided to the NF trainees. This (fabricated) bar graph illustrates that the trainee is learning less effectively (lower 'learning score %') than the (fabricated) group.

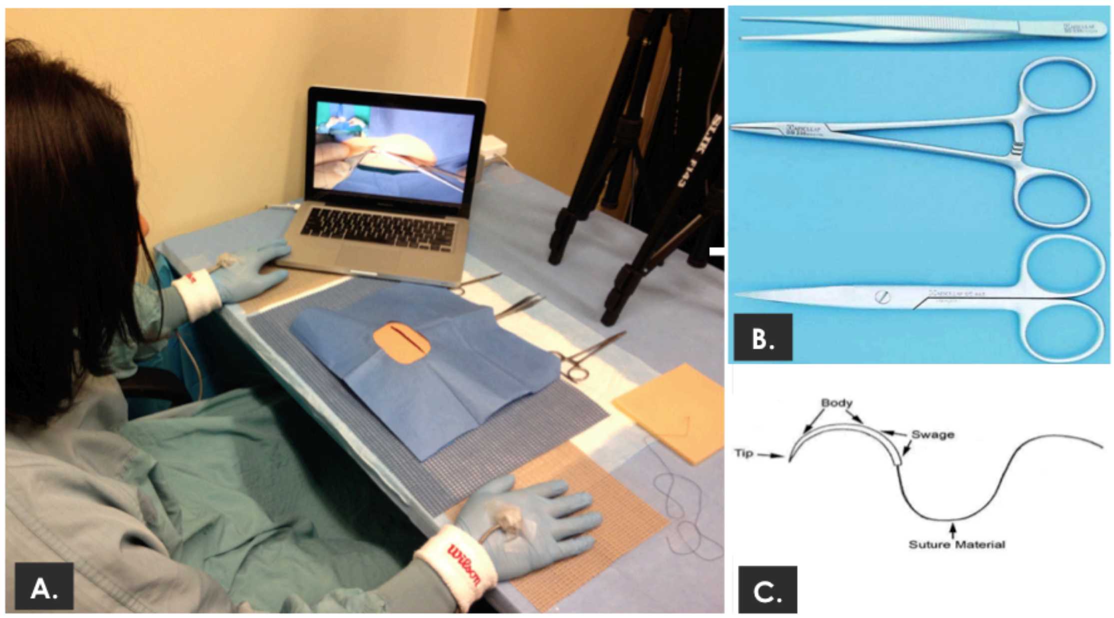

Figure 2.6. Suturing tools/material and experimental set-up for suturing portion of the study. **A.** Trainee, gowned and gloved, seated in front of draped artificial skin and suturing tools, and watching an expert suture training video; **B.** Suturing tools (from top to bottom): forceps, needle driver, suture scissors; **C.** Suture needle.

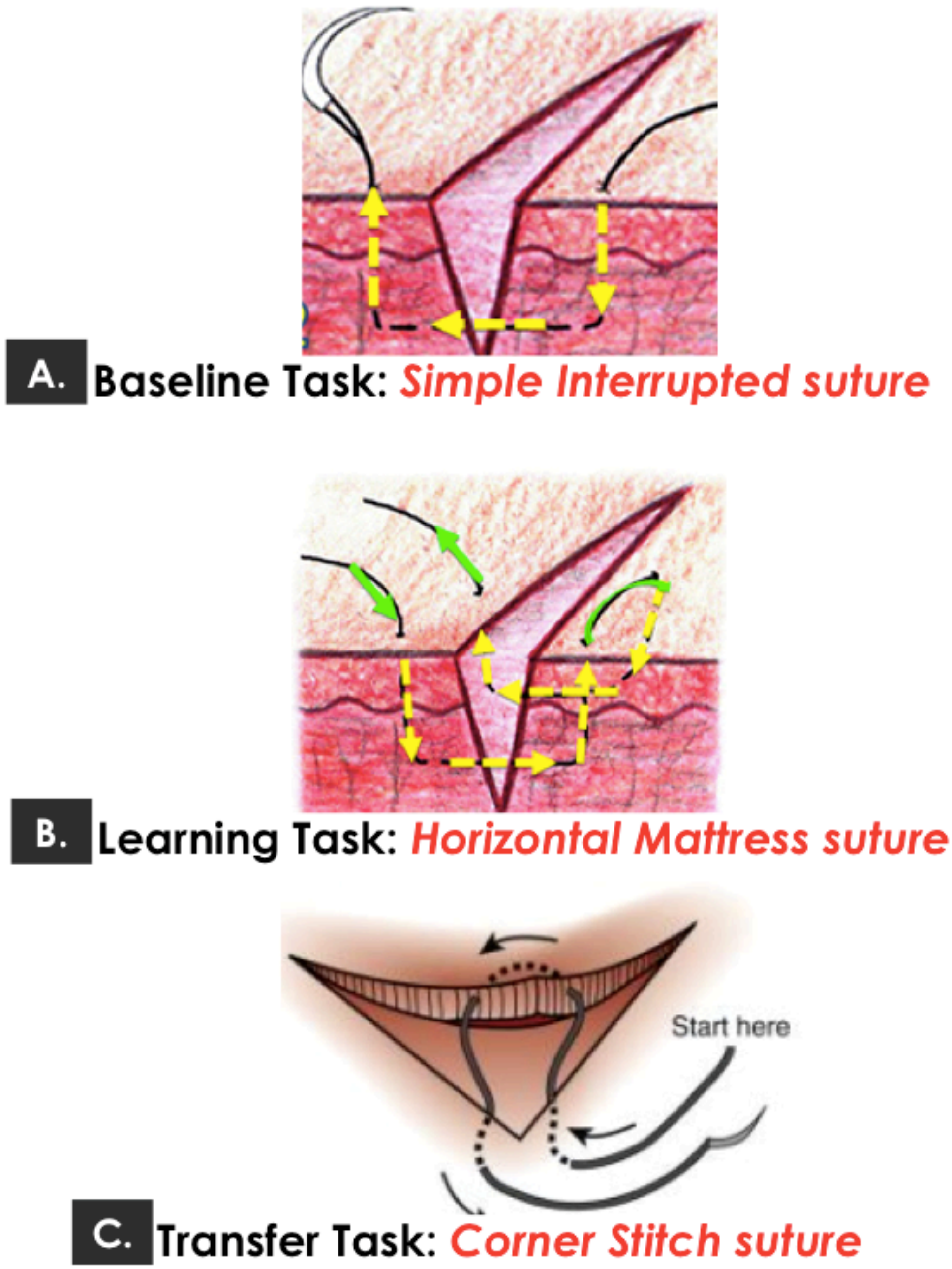

Figure 2.7. Types of sutures performed during sessions 1 and 2 of the experiment. Suturing complexity increased across the suturing techniques. **A.** Simple interrupted suture; **B.** Horizontal mattress suture; **C.** Corner stitch suture (also termed half-buried horizontal mattress suture).

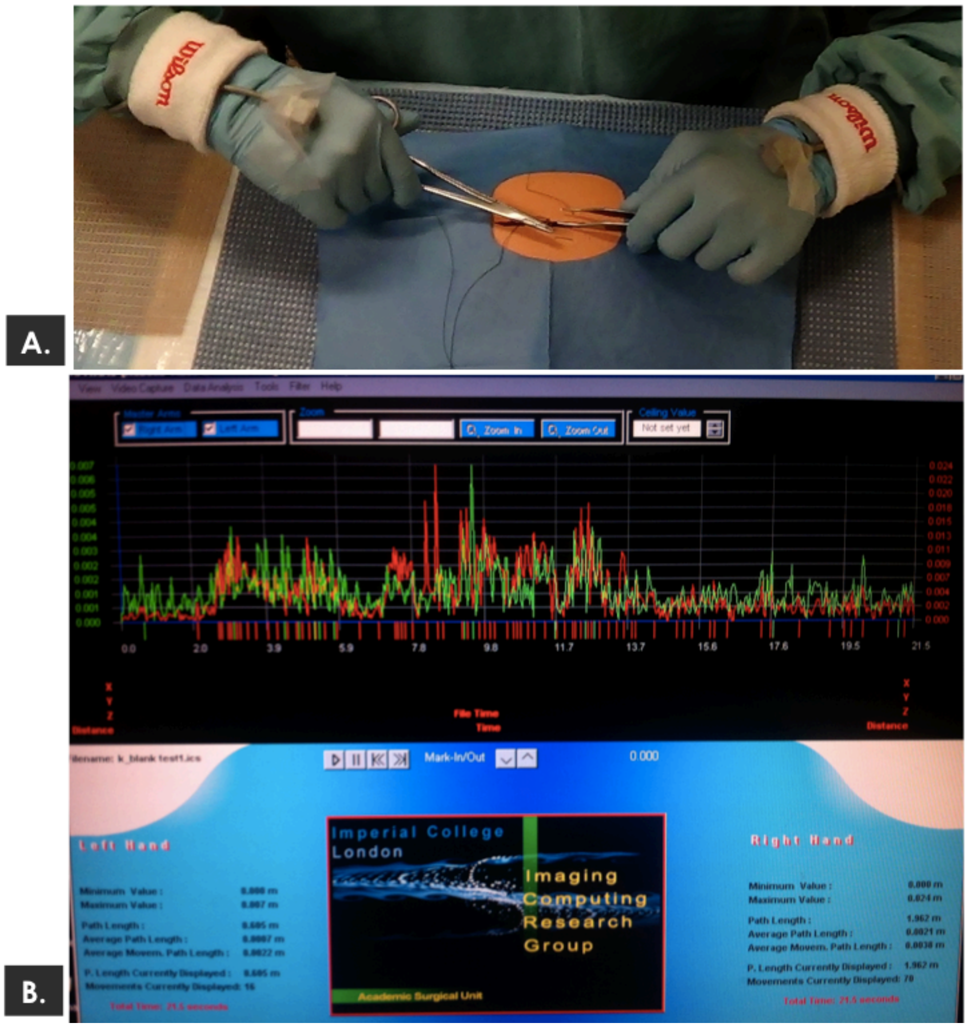

Figure 2.8. Imperial College Surgical Assessment Device (ICSAD) motion capture system used during the suturing portion of the experiment. **A.** ICSAD markers, placed on the dorsum of each gloved hand, to capture hand motion data; **B.** Screenshot of ICSAD output, including the extracted variables of interest (total time and number of hand movements).

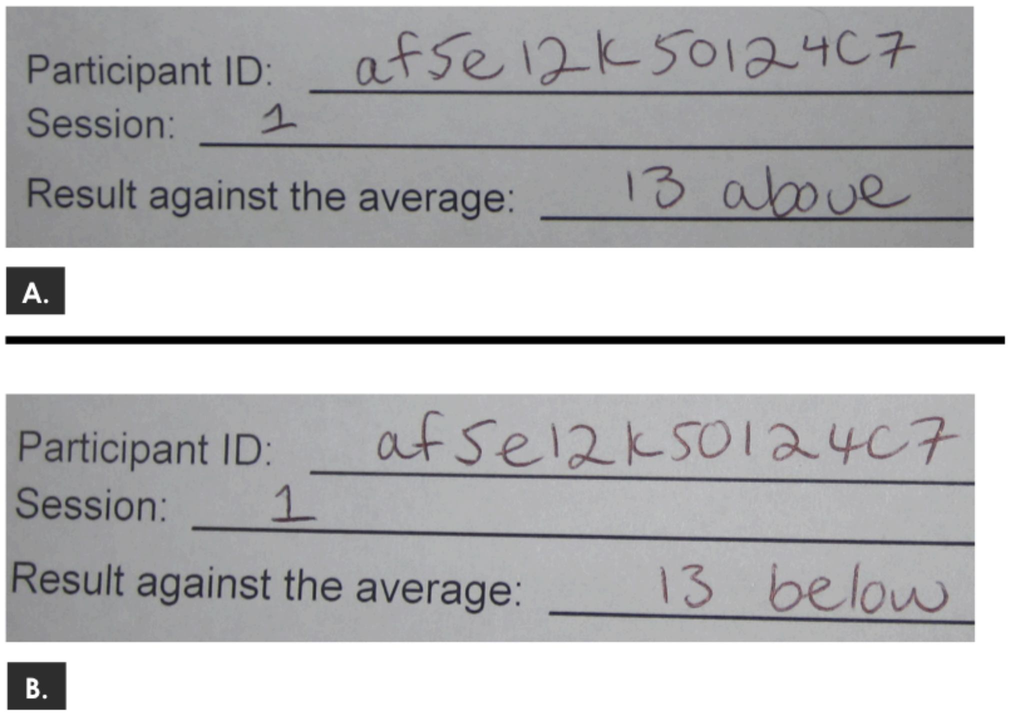

Figure 2.9. An example of the performance summaries that the PF and NF trainees received during the suturing acquisition phase. These performance summaries were provided following the simple interrupted suture and at the end of practice for the horizontal mattress suture (the first and second performance summary averaged to 14, above or below the average). **A.** An example of a performance summary provided to the PF trainees, which indicates that the trainee is performing above the average; **B.** An example of a performance summary provided to the NF trainees, which indicates that the trainee is performing below the average.

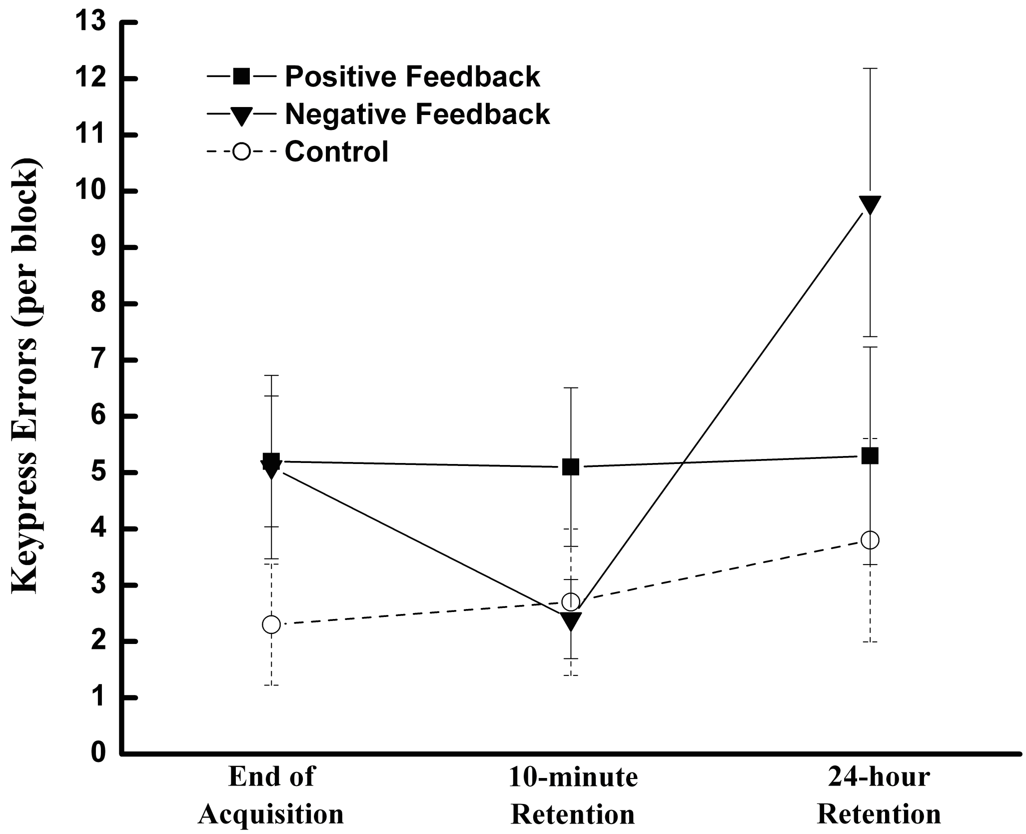

Figure 2.10. Key-press errors for the PF, NF, and CF groups across the last block of acquisition, same-day retention, and delayed-retention (24 hours later). Each block consists of 16 trials (four of each colour pattern). Error bars represent standard error of the mean.

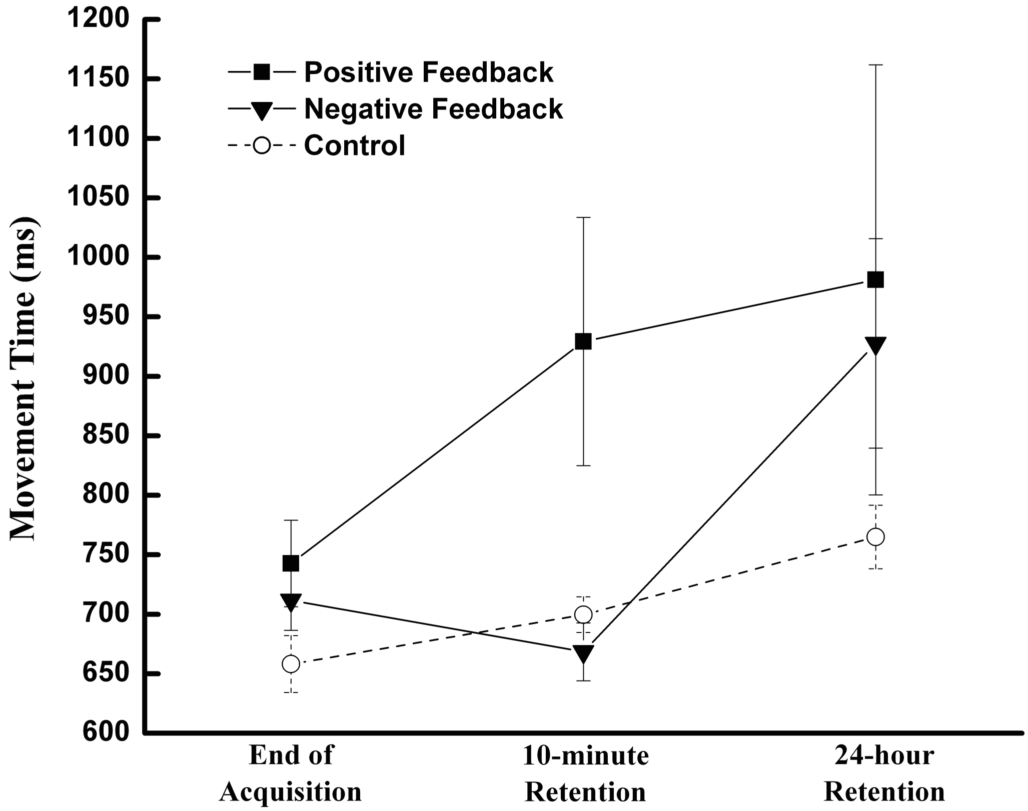

Figure 2.11. Movement time (MT) for the PF, NF, and CF groups across the last block of acquisition, same-day retention, and delayed-retention (24 hours later). Each block consists of 16 trials (four of each colour pattern). Error bars represent standard error of the mean.

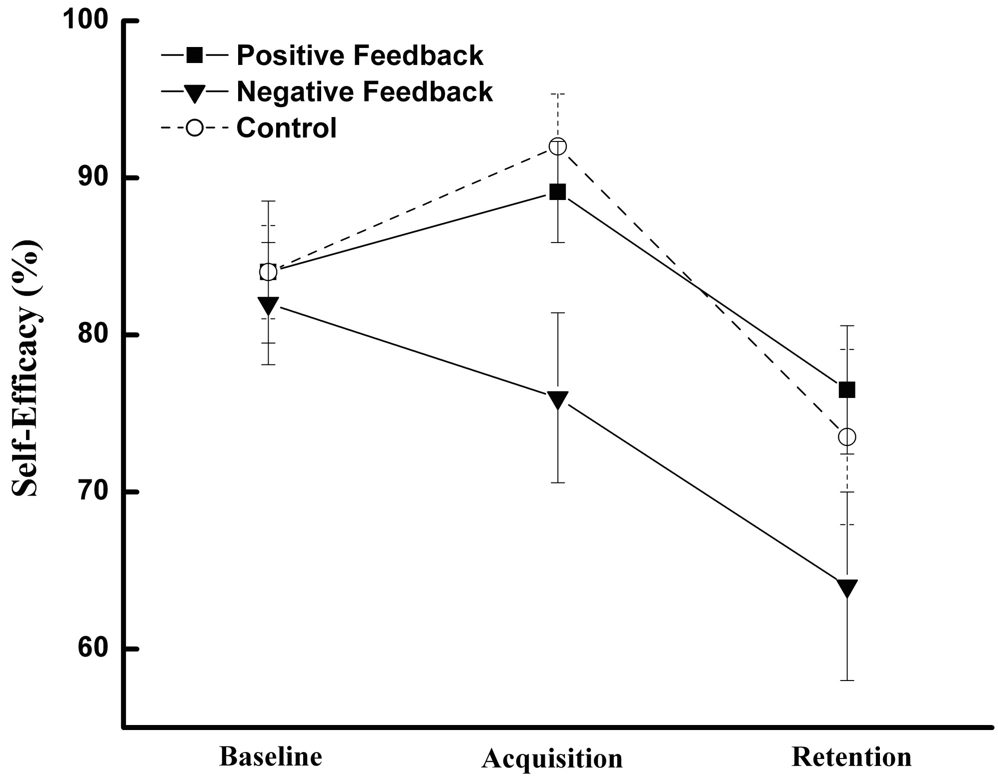

Figure 2.12. Key-pressing self-efficacy ratings for the PF, NF, and CF groups prior to any feedback manipulation (baseline), following feedback manipulation (but prior to acquisition), and pre-delayed retention (24 hours later). Error bars represent standard error of the mean.

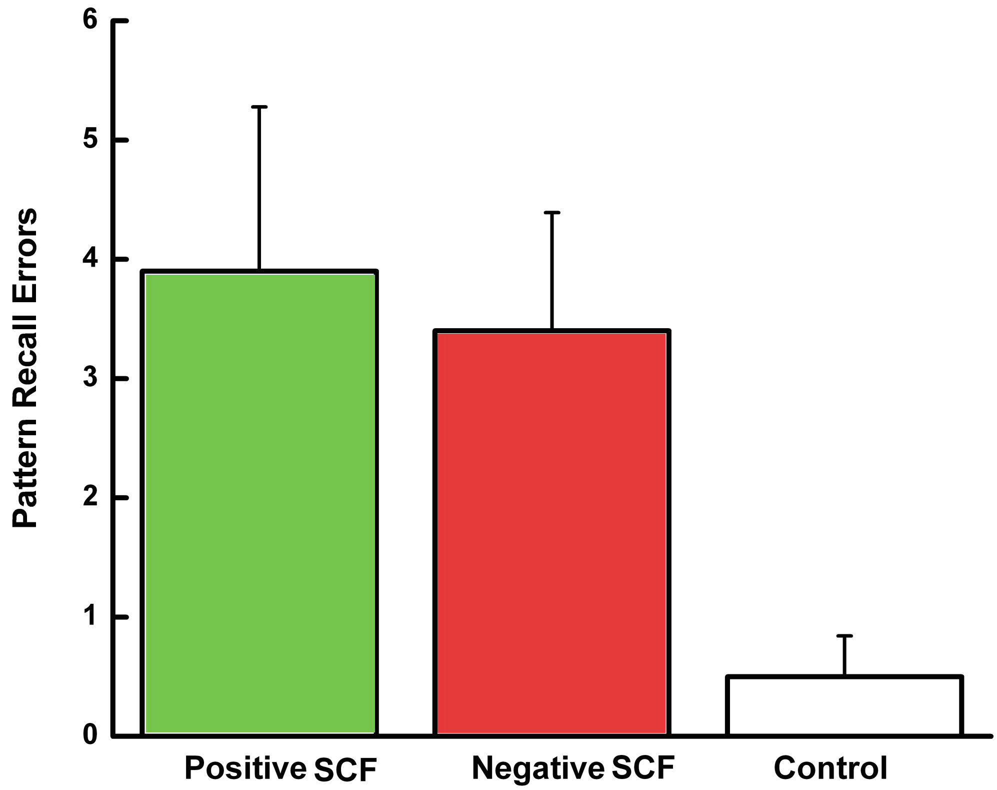

Figure 2.13. Pattern recall errors for PF, NF, and CF groups during the uncued recall test completed during *Session 2* testing (24 hours later). Error bars represent standard error of the mean.

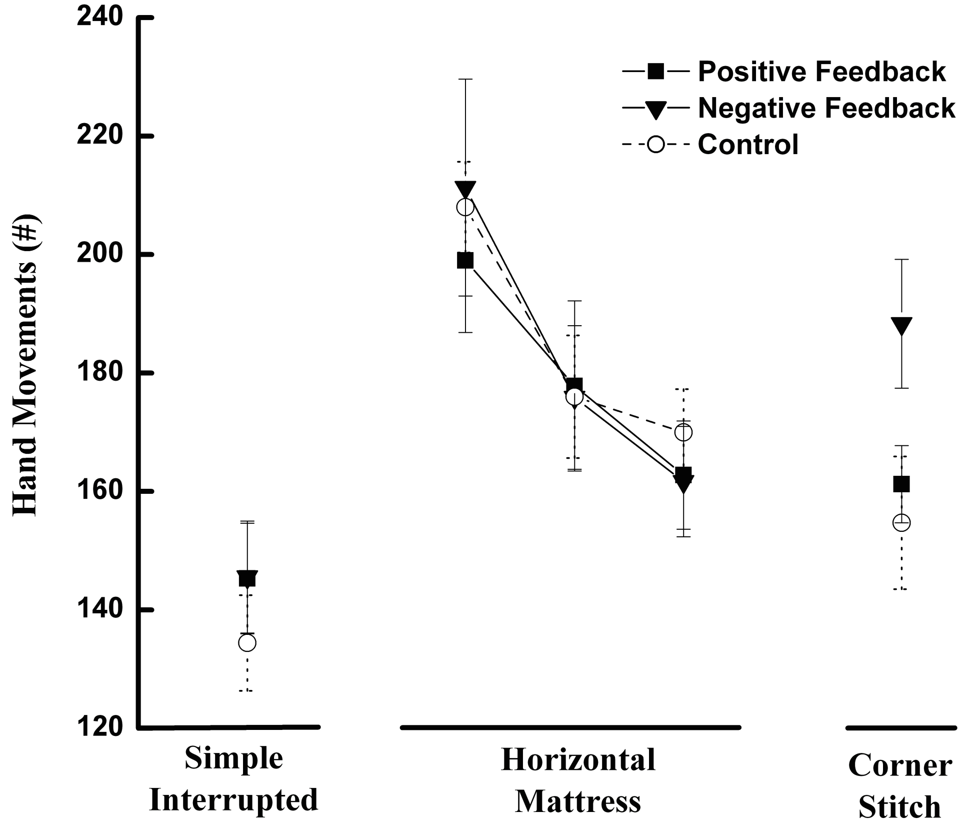

Figure 2.14. Number of Hand Movements (ICSAD measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (24 hours later). Error bars represent standard error of the mean.

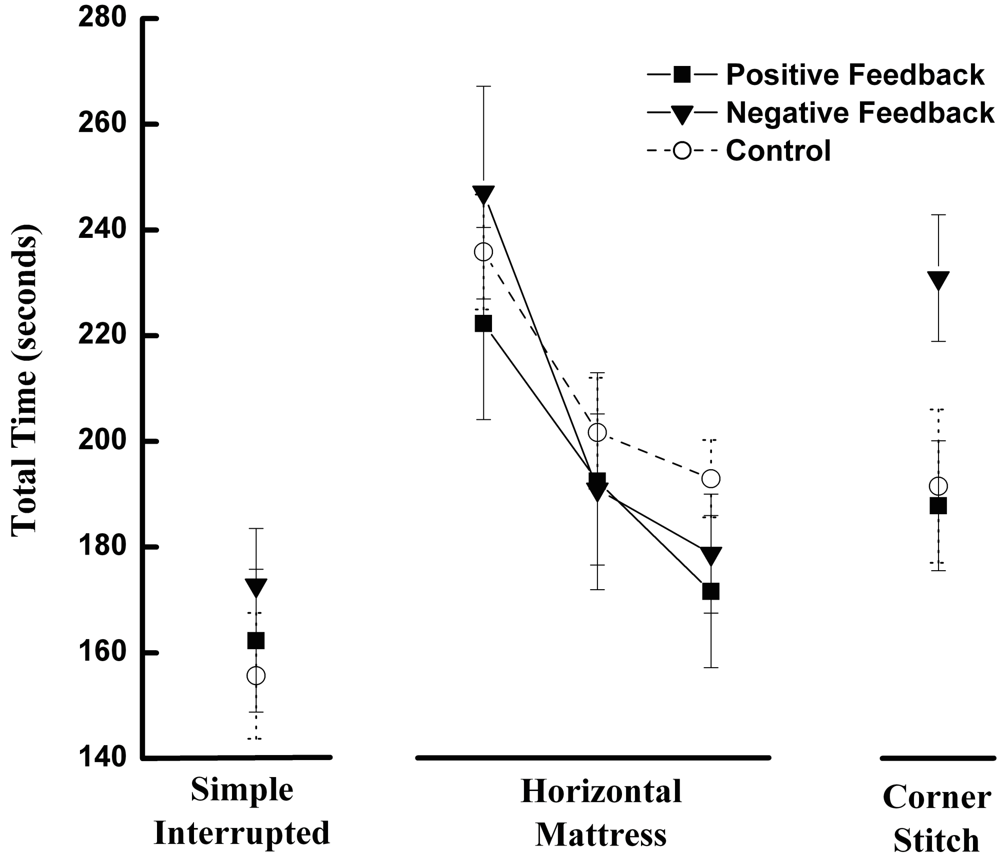

Figure 2.15. Total (suture) Time (ICSAD measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (24 hours later). Error bars represent standard error of the mean.

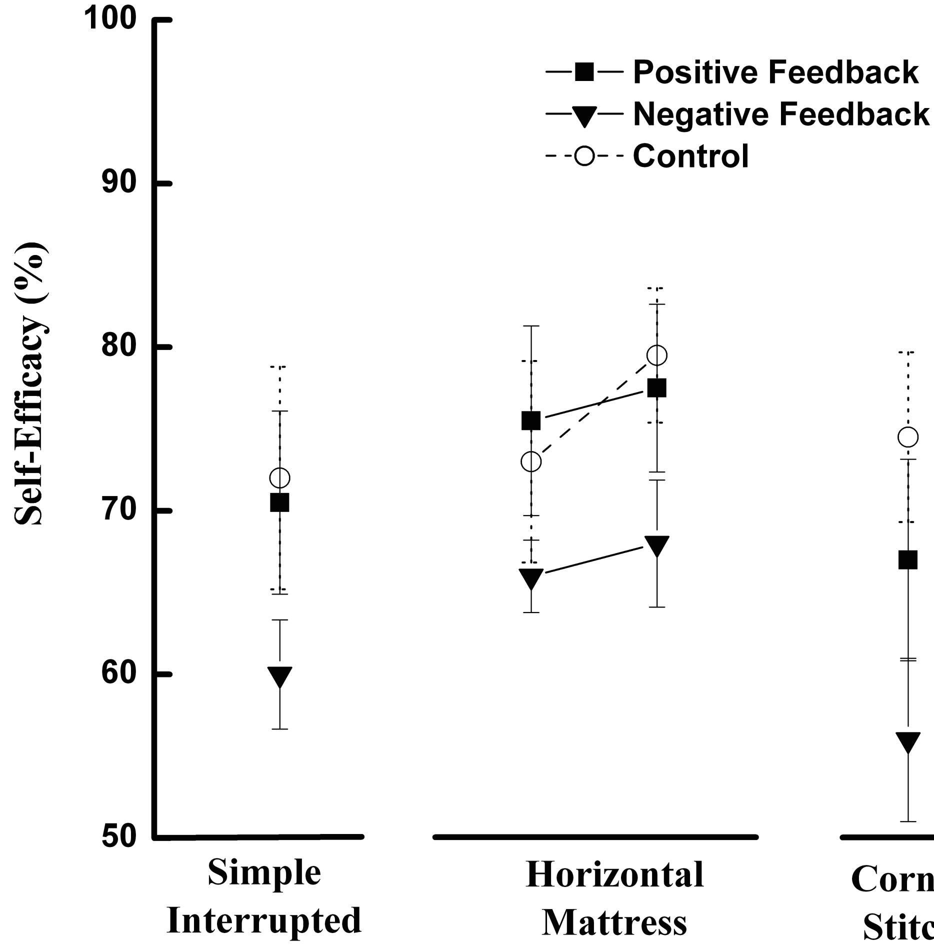

Figure 2.16. Suturing self-efficacy ratings for the PF, NF, and CF groups prior to performing the simple interrupted suture and the horizontal mattress suture during *Session 1* and prior to performing the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (24 hours later). Error bars represent standard error of the mean.

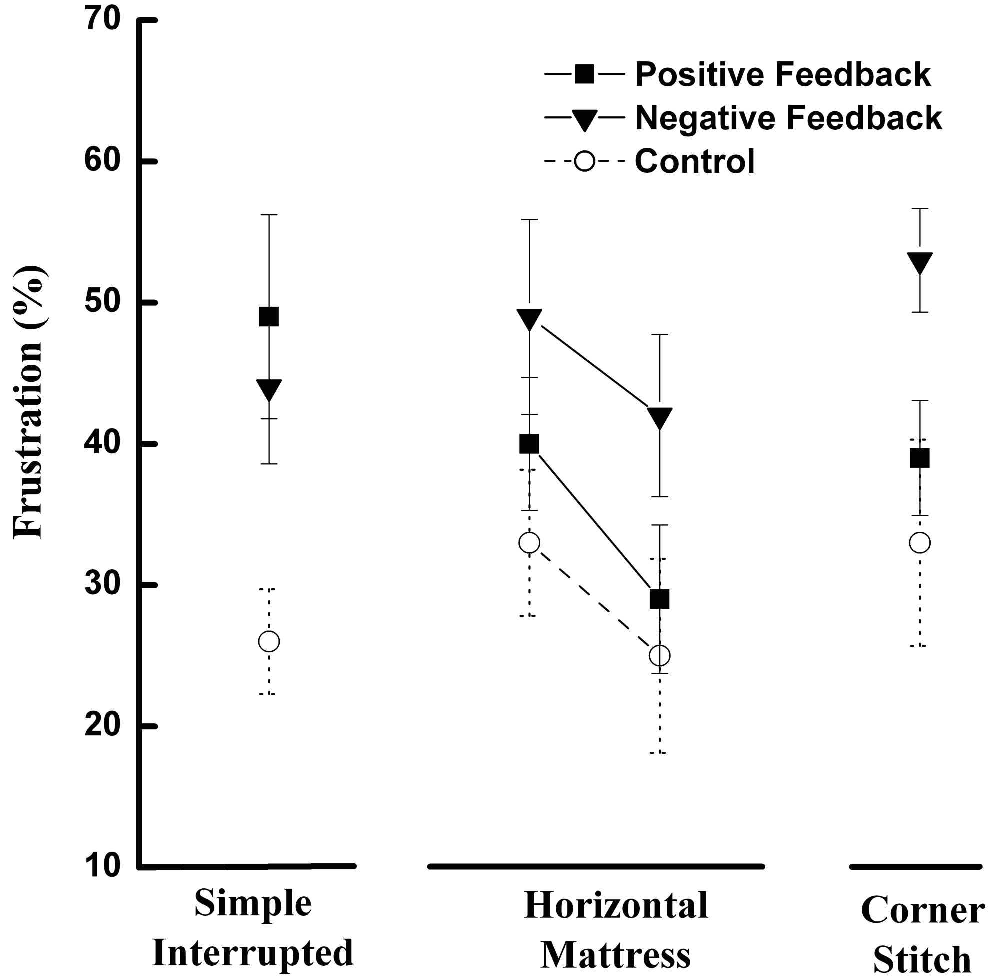

Figure 2.17. Suturing frustration ratings for the PF, NF, and CF groups following the performance of the simple interrupted suture and the horizontal mattress suture during *Session 1* and following the performance of the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (24 hours later). Error bars represent standard error of the mean.

Table 2.1: Participant demographics and psychological ratings

	Positive Social-Comparative Feedback (PF) n=10 *M* (*SD*)		Negative Social-Comparative Feedback (NF) n=10 *M* (*SD*)		Control (CF) n=10 *M* (*SD*)	
Age	22.1	(1.2)	23.9	(5.1)	22.5	(1.3)
Situational Motivation (7-pt scale)						
Intrinsic Motivation	5.3	(0.7)	5.0	(0.6)	5.5	(1.0)
Identified Regulation	5.9	(0.5)	6.0	(0.5)	6.1	(0.6)
External Regulation	1.7	(0.8)	2.4	(0.9)	2.1	(1.0)
Amotivation	1.5	(0.3)	1.9	(0.8)	1.4	(0.4)
Global Self-esteem (5-pt scale)	3.7	(0.7)	4.1	(0.6)	3.9	(0.7)
Key-press: Self-efficacy (/100%)						
Baseline (pre-manipulation)	84.0	(14.3)	82.0	(12.3)	84.0	(9.4)
Acquisition (post-manipulation)	89.1	(10.2)	76.0	(17.1)	92.0	(10.6)
Retention	76.5	(12.9)	64.0	(19.0)	73.5	(17.6)
Suturing: Importance (/100%)	82.0	(11.4)	80.0	(13.3)	76.0	(20.1)
Suturing: Self-efficacy (/100%)						
SI	70.5	(17.7)	60.0	(10.5)	72.0	(21.5)
HM Acquisition	75.5	(18.3)	66.0	(7.0)	73.0	(19.5)
HM Retention	77.5	(16.2)	68.0	(12.3)	79.5	(13.0)
CS	67.0	(19.5)	56.0	(15.8)	74.5	(16.4)
SI: NASA (/100%)						
Mental Demand	70.0	(17.0)	61.0	(12.0)	57.5	(21.8)
Effort	71.0	(13.7)	58.0	(19.3)	62.0	(19.3)
Performance	62.0	(16.9)	58.0	(16.2)	66.0	(18.4)
Frustration	49.0	(22.8)	44.0	(17.1)	26.0	(11.7)
HM Acquisition: NASA (/100%)						
Mental Demand	76.0	(17.8)	69.0	(11.0)	68.0	(19.9)
Effort	72.0	(12.3)	71.0	(9.9)	68.0	(19.9)
Performance	73.5	(19.2)	57.0	(16.4)	59.0	(21.3)
Frustration	40.0	(14.9)	49.0	(21.8)	33.0	(16.4)
HM Retention: NASA (/100%)						
Mental Demand	62.0	(16.9)	59.0	(13.7)	57.0	(22.6)
Effort	60.0	(15.6)	60.0	(15.6)	51.0	(21.3)
Performance	72.0	(12.3)	60.0	(20.0)	67.0	(14.2)
Frustration	29.0	(16.6)	42.0	(18.1)	25.0	(21.7)
CS: NASA (/100%)						
Mental Demand	70.0	(12.5)	77.0	(6.7)	72.0	(16.9)
Effort	68.0	(11.4)	72.0	(6.3)	70.0	(20.0)
Performance	59.0	(17.9)	51.0	(21.3)	58.0	(23.9)
Frustration	39.0	(12.9)	53.0	(11.6)	33.0	(23.1)

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

Table 2.2: Participant behavioural outcomes on key-pressing and suturing

	Positive Social-Comparative Feedback (PF) n=10 *M* (*SD*)		Negative Social-Comparative Feedback (NF) n=10 *M* (*SD*)		Control (CF) n=10 *M* (*SD*)	
Key-press blocks: Movement Time (blocks of 16 trials)						
End of Acquisition	742.7	(115.0)	711.8	(79.9)	658.2	(75.5)
Immediate Retention	929.2	(329.9)	668.4	(76.8)	699.6	(47.3)
Delayed Retention	981.1	(571.4)	927.6	(278.5)	765.0	(84.6)
Key-press blocks: ERROR (blocks of 16 trials)						
End of Acquisition	5.2	(3.7)	5.1	(5.2)	2.3	(3.4)
Immediate Retention	5.1	(4.5)	2.4	(2.2)	2.7	(4.1)
Delayed Retention	5.3	(6.1)	9.8	(7.5)	3.8	(5.7)
Key-press: Recall Errors	3.9	(4.4)	3.4	(3.1)	0.5	(1.1)
Suturing trials: Total Time						
SI trial 1	182.3	(43.1)	189.4	(44.1)	170.9	(38.3)
SI trial 2	142.2	(46.2)	156.1	(34.4)	140.5	(35.1)
HM1 trial 1	236.5	(53.1)	273.4	(74.1)	255.9	(51.4)
HM2 trial 1	200.1	(62.7)	206.5	(61.8)	214.1	(32.6)
HM3 trial 1	174.0	(49.3)	184.5	(32.3)	208.6	(49.3)
HM1 trial 2	208.1	(63.5)	220.8	(54.8)	215.8	(29.6)
HM2 trial 2	184.9	(68.1)	175.4	(40.9)	189.3	(35.2)
HM3 trial 2	169.2	(44.1)	173.0	(41.6)	177.3	(43.5)
CS trial 1	187.8	(38.9)	230.9	(37.9)	191.5	(37.7)
Suturing trials: Hand Movements						
SI trial 1	162.3	(35.7)	153.8	(41.4)	142.5	(34.6)
SI trial 2	128.3	(27.5)	137.3	(25.8)	126.3	(18.4)
HM1 trial 1	207.1	(39.1)	227.4	(66.2)	215.9	(37.7)
HM2 trial 1	184.6	(42.5)	187.6	(51.2)	187.1	(24.2)
HM3 trial 1	169.5	(35.0)	170.7	(29.0)	182.0	(42.4)
HM1 trial 2	190.9	(41.5)	195.2	(50.7)	200.1	(36.2)
HM2 trial 2	171.0	(49.7)	164.1	(33.6)	164.9	(26.8)
HM3 trial 2	156.0	(30.4)	152.6	(32.0)	157.9	(30.0)
CS trial 1	161.2	(20.6)	188.3	(34.4)	154.7	(25.5)
Practice sutures: Total Number						
SI (in 15m)	4.1	(0.3)	3.3	(0.7)	4.0	(0.7)
HM (in 10m)	1.8	(0.6)	1.9	(0.7)	1.7	(0.7)
Number of participants who watched video during practice						
SI	2/10	-	10/10	-	7/10	-
HM	2/10	-	10/10	-	8/10	-
Number of participants that adopted specific strategies related to performing suturing techniques						
Strategies before task	9/10	-	0/10	-	8/10	-
Strategies during task	0/10	-	9/10	-	0/10	-
Strategies before and during task	1/10	-	1/10	-	2/10	-

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; HM1 = first set of horizontal mattress sutures completed during *Session 1*; HM2 = second set of horizontal mattress sutures completed during *Session 1*; HM3 = third set of horizontal mattress sutures completed during *Session 2*; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

CHAPTER 3:

THE EFFECTS OF SOCIAL-COMPARATIVE FEEDBACK IN MEDICAL TRAINEES LEARNING PROCEDURAL SKILLS

3.1 – ABSTRACT

Our previous research (Study 1, Chapter 2) provides the first demonstration that medical trainees, a subset of highly-motivated learners, do not respond to social-comparative feedback in the same manner as other learners do. Contrary to a recent yet robust line of research (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012 (Experiment 1); Wulf & Lewthwaite, 2016), our previous work (Study 1, Chapter 2) indicates that highly-motivated learners such as medical trainees do not benefit psychologically or behaviourally from receiving positive social-comparative feedback during the acquisition of two different types of motor tasks (e.g., a basic laboratory motor task and technical skill task). In fact, receiving positive social-comparative feedback during the acquisition of a less training-relevant task (i.e., computer key-pressing) became detrimental to the learning process. Also, contrary to previous research (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf & Lewthwaite, 2016), trainees receiving below-average information during the acquisition of both tasks (regardless of how they actually performed) experienced significant psychological and behavioural degradation relative to the learning process.

The purpose of this study was to extend the Study 1 (Chapter 2) results to a more clinically-relevant context and in order to do so, we made specific methodological changes to this study. Since we were specifically interested in focusing on the psychological and behavioural effects of social-comparative

feedback on technical skill acquisition (i.e., suturing), the training-irrelevant task (computer key-pressing) was removed from the methodological design. We expected that this procedural change would result in a stronger feedback effect (since potential task carry-over effects were a concern in the previous study). We also included gold-standard clinical expert assessment measures for the suturing tasks (global rating scale and procedural checklist). In order to encourage a more clinically-relevant feedback scenario, the frequency of the feedback delivery in this study was also modified. Specifically, we decreased the frequency of the feedback delivery from seven instances (Study 1) to two (present study), in order to better represent feedback interactions in clinical education. The final procedural change included an increase in the retention delay time (from 24 to 48 hours) in order to examine how robust and stable the learning effects were by adding in another 24-hour delay.

During the surgical skill acquisition phase, novice medical trainees were randomly assigned to receive no social-comparative feedback (control) or fabricated performance summaries indicating that they were performing better or worse than their peers, regardless of their actual performance. Adopting a better-than-average mindset did not facilitate technical skill acquisition compared to the control condition; however, trainees receiving negative social-comparative feedback experienced detriments to their psychological and behavioural outcomes during the learning process. Our findings suggest that there may be a significant and heretofore unreported relationship between negative social-comparative feedback and mindset that modifies performance, learning, and self-efficacy beliefs in highly-motivated learners acquiring a personally relevant motor skill (e.g., medical trainees acquiring basic suturing techniques).

3.2 – INTRODUCTION

Since feedback is rarely neutral, how it is presented is critical in influencing motivation, performance, and skill learning. Previous research shows that positive SCF feedback can be beneficial for learners (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2010, 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2016); however, this is *not* the case for learners with higher motivation (i.e., novice medical trainees) (Study 1, Chapter 2). Previous research also demonstrates that non-medical learners are not sensitive, at least on a behavioural level, to receiving below-average feedback (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf & Lewthwaite, 2016); however, our previous work (Study 1, Chapter 2) suggests that highly-motivated learners like medical trainees experience difficulty in receiving below-average information. This is reflected in detriments that were observed with respect to psychological outcomes such as self-efficacy and frustration ratings, in addition to their learning of different motor tasks (Study 1, Chapter 2). In other words, the novice medical trainees in our previous study, who were representative of a subset of highly-motivated learners, had difficulty coping with information that they were performing worse than their peers – regardless of their actual performance and regardless of the motor task they were learning (i.e., a less-relevant computer key-pressing task or a more-relevant suturing task). Our previous study (Study 1, Chapter 2), although demonstrating that medical trainees were responding to social-comparative feedback differently, was not however, methodologically designed to be realistic of a typical feedback encounter found in a clinical setting (e.g., as per the frequency of feedback delivery and the specific tasks that the trainees were required to learn). The purpose of this study was to extend the findings from Study 1 (Chapter 2) by implementing specific methodological changes that would a) explore how robust and stable the learning effects were (by increasing the retention delay), and b) better simulate an actual feedback encounter in clinical education (discussed next).

Although feedback in clinical education has been portrayed as being the ‘cornerstone of effective clinical teaching’ (Cantillon & Sargeant, 2008), most would agree that it is far from being the effective feedback conversation that it aspires to be. In fact, feedback in clinical education is a major problem from both the perspective of the feedback provider and the feedback receiver (Archer, 2010; Branch & Paranjape, 2002; Ende, 1983; Ende, Pomerantz, & Erickson, 1995; McIlwrick, Nair, & Montgomery, 2006; Molloy, 2009; Lefroy et al., 2015; Teunissen, Stapel, van der Vleuten, Scherpbier, Boor, & Scheele, 2009). From the perspective of the feedback provider, clinical educators report feedback conversations (particularly negative ones) as being challenging interactions that are uncomfortable and even feared (Ende, 1983; Molloy, 2009). From the feedback receiver’s perspective, medical trainees are not satisfied with the quantity or quality of feedback that they receive during their training (Bing-You & Trowbridge, 2009; Cantillon & Sargeant, 2008; Delva et al., 2013; Gil et al., 1984; Isaacson et al., 1995; Kogan et al., 2000; Robins et al., 1997; Sumit et al., 2004).

The nature of the clinical setting also makes it difficult, if not impossible, for a standardized feedback interaction to occur. Feedback delivery in clinical education is best described as being *diverse* – largely ranging in the type, the context, and the source of the information (Archer, 2010; Lefroy et al., 2015; Molloy, 2009). It is not realistic for a trainee to receive seven instances of feedback during one learning opportunity in a clinical setting (as trainees were provided with during Study 1). The ambivalence related to feedback interactions could also contribute to trainees not even being aware that that feedback has been or is being provided (Archer, 2010; Molloy, 2009). As an alternative to creating meaningful feedback interactions, the most common type of feedback that is incorporated into medical training is the delivery of social-comparative feedback (Harrison et al., 2013). This type of feedback provides trainees with their performance scores relative to their peers. Social-comparative feedback has been shown to be a quick, unbiased/uniform and less resource-intensive way to provide trainees with feedback (Lefroy et al., 2015). At a first glance, the use of social-comparative feedback appears to be a resolution to the feedback problem, and is embraced by both trainees and clinical educators. Trainees report that they enjoy and prefer to receive it (Raat et al., 2010; Watling, 2014a), while clinical educators are provided with the opportunity to avoid having to engage in a less desirable feedback conversation. However, based on the recent feedback guidelines proposed for clinical education, Lefroy et al. (2015) suggest that we currently do not know the impact that social feedback has on medical trainees. Moreover, our previous work (Study 1, Chapter 2) suggests that, particularly below-average feedback, is detrimental on a psychological and behavioural level for novice medical trainees; however, in Study 1 we explored the effects of social-comparative feedback on both a training-relevant (suturing) and -irrelevant task (computer key-pressing). The methodological design that was implemented in Study 1 was specific to the nature of the research questions that were asked in Study 1. Some of the limitations in Study 1 included a lack of realism to clinical feedback encounters and the potential of task carry-over effects. Therefore, this warrants further study, as we need to at least understand the feedback scenarios that medical students are receiving during their training (mainly social comparative feedback and related to specific clinical skills) as well as the different contexts in which this type of feedback could be potentially harmful to trainees.

With major shifts being evident in health care (e.g., trainee duty hour restrictions, different types of patients, shift away from the traditional 'apprenticeship model'), the use of simulation as a platform for learning has rapidly increased in medical training (Lateef, 2010; Reznick & MacRae, 2006) in order to help ensure that trainees are exposed to the necessary clinical experiences that will help their transition to independent practice. Simulations in medical training are primarily designed to include practical and relevant skill training.

Since the key-pressing task that we used in Study 1 was not relevant to medical training, we removed it from the methodological design in this study.

Since medicine often creates instructional settings carrying elevated costs of failure, these evident tensions related to feedback interactions have significant implications for both training and transition to independent clinical practice. Therefore, the purpose of this study was to extend our previous results (Study 1, Chapter 2) related to exploring feedback encounters in medical trainees, to a more clinically-relevant context (i.e., by creating a more realistic feedback encounter that would more closely mimic what medical trainees would experience in terms of feedback delivery in a clinical education setting). We aimed to do this by modifying the following three methodological decisions from our previous study: 1) removing the training-irrelevant task from the equation (computer key-pressing) and only focusing on the task of suturing, 2) increasing the skill retention delay following feedback delivery (from 24 to 48 hours), and 3) providing the social-comparative feedback at a lower frequency (twice compared to seven times). In addition to the procedural changes, we also included gold standard measures of technical skill performance for this study (i.e., expert assessment of the suturing task) to examine the clinically-relevant effects of social-comparative feedback during a training-relevant task (suturing). Moreover, we expected that removing the training-irrelevant task (key-pressing) that was used in Study 1 would help create a more realistic feedback delivery event that would better mimic what trainees would experience in a clinical setting, and as a result we expected this methodological change to increase the effect of the social-comparative feedback. Based on our previous findings (Study 1), we expected that the delivery of positive social-comparative feedback would not elicit any differences compared to a control condition, whereas the delivery of negative social-comparative feedback would be detrimental to both psychological and behavioural outcomes.

3.3 – METHODS

3.3.1 – *Participants*

Thirty novice pre-clerkship (years 1 and 2) medical trainees (15 female) with a mean age of 24.13 (*SD* = 2.27) from the University of Toronto participated in this study. Ethical approval was obtained from the home institutional site (i.e., McMaster University, #2012187) as well as the data collection site (i.e., University of Toronto, #28391). Data collection consisted of two sessions 48 hours apart for a total time commitment of approximately three hours. Each trainee was compensated 20 dollars upon study completion (*Session 1* and *2*).

Prior to data collection all trainees completed the SIMS (Guay et al., 2000) and SISE (Robins et al., 2001) scales that were used in Study 1 (Chapter 2) as a baseline measure of learner motivation (see Table 3.1 for specific values). These measures, in combination with those found in literature (Ferguson et al., 2002; Hutchins, 1964; Kusurkar et al., 2011; Mattick & Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner &

Nicholson, 2011), established that the trainees recruited for this study represented a subset of highly-motivated learners.

Trainees were randomly assigned to one of three groups, where during *Session 1* the:

Positive social-comparative feedback group (PF): received **positive** social-comparative feedback following the first and second suturing task;

Negative social-comparative feedback group (NF): received **negative** social-comparative feedback following the first and second suturing task;

Control group (CF): received **no** social-comparative feedback following the suturing tasks.

Following data collection and the manipulation check, trainees were debriefed[14] on the true nature of the experiment, asked to re-consent to the experimental protocol and also provided with the option to receive their actual performance scores post-data collection.

3.3.2 – *Experimental Apparatus And Task*

The task and apparatus used for this study were identical to those used in the suturing portion of Study 1 (Chapter 2). Specific methodological modifications that were made will be described next.

[14] The debriefing session ensured that trainees understood that the feedback they had received during the experiment was entirely manipulated by the experimenters and did not at all reflect their actual performance and ability to learn the suturing techniques.

3.3.3 – *Experimental Protocol*[15]

Since the training-irrelevant task (computer key-pressing) was removed for this study, trainees were allocated with more practice time for the suturing techniques (i.e., simple interrupted suture and horizontal mattress suture). A total time of 25 $\pm$ 2 minutes was allocated for practicing the simple interrupted suture (compared to 15 $\pm$ 2 minutes that was provided in Study 1), and 15 $\pm$ 2 minutes was allocated for practicing the horizontal mattress suture (compared to 10 $\pm$ 2 minutes that was provided in Study 1).

The feedback presentation and frequency for the two feedback groups (PF and NF) were also modified for this study. Specifically, trainees in the two feedback conditions received two instances of social-comparative feedback that were congruent to initial group assignment (compared to 7 instances that were provided in Study 1) (see Figure 3.2 A and C for the feedback presentation details of the first instance and Figure 3.2 B and D for the second instance).

The final procedural change included the increase in the retention delay time, where trainees returned for *Session 2* after a 48-hour delay (compared to the 24-hour delay in Study 1).

3.3.4 – *Outcome Measures*

Psychological Measures

Motivational Profile. SIMS (Guay et al., 2000) and SISE (Robins et al., 2001) scales that were used in Study 1 were also used in this study. Internal

[15] Figure 3.1 illustrates a schematic of the experimental design.

consistency for each subscale of SIMS in this study was as follows: intrinsic motivation Cronbach's $\alpha = .66$, identified regulation Cronbach's $\alpha = .72$, external regulation Cronbach's $\alpha = .75$, amotivation Cronbach's $\alpha = .77$. Internal consistency was acceptable (above .70) for all subscales except intrinsic motivation (Nunnally & Bernstein, 1994). No intrinsic motivation items were deleted to increase consistency for this subscale so that these results can be compared against other studies using the same scale.

Task-Specific Self-Efficacy. Self-reported self-efficacy that was used in Study 1 was also used in this study.

Mental Demand, Effort, Performance, Frustration. Self-reported mental demand, effort, performance and frustration subscales from the NASA-TLX questionnaire (Hart & Staveland, 1988) that were used in Study 1 were also used in this study.

<u>Behavioural Measures</u>

Expert Assessment – Global Rating Scale And Checklist. The global rating scale (GRS) and procedural checklist (CL) were two assessment measures that were added to this study. The gold standard for objectively assessing procedural skills like suturing is through expert assessment on GRS and CL (Cohen, Rothman, Poldre, & Ross, 1991; Faulkner, Regehr, Martin, & Reznick, 1996; Martin et al., 1997; Regehr, MacRae, Reznick, & Szalay, 1998; Reznick & MacRae, 2006; Winckle, Reznick, Cohen, & Taylor, 1994). Both scoring systems were used for this experiment even though the correlation between GRS and CL scores is typically high[16] (Martin et al., 1997).

Following data collection, each of the nine recorded testing trials (two simple interrupted and four horizontal mattress trials during session 1; two horizontal mattress trials and one corner stitch trial during session 2), for a total of 270 video recordings, were scored by two blinded senior surgical fellows using the suturing-specific GRS and CL. The raters scored the trainees' videotaped performances using a validated five item 5-point Likert suturing-specific GRS scale (maximum score of 25) and a validated 10 dichotomous item suturing-specific CL scale (maximum score of 10) with each item being scored as 'done correctly' or 'done incorrectly'.

Suturing performance was filmed using two separate high-definition Panasonic 16GB HC-V100M camcorders. Both camera views[17] were synced together, rotated 180 degrees and edited to a split-screen format using Adobe Premiere Pro CS6, so that raters had a first-person multi-view perspective when evaluating trainee performance on the two assessment scales. All videos were de-identified and coded.

The two raters underwent calibration training[18] before independently

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[16] Martin and colleagues (1997) suggest that the GRS scoring system is more reliable, requires less rater training and could be used alone for assessment.

[17] The two camera views included the 'far' camera, which provided an overall view of the participant's hands and the 'near' camera, which provided a close-up view at the level of the laceration.

[18] The two raters met with the primary investigator and were trained to use to the GRS and CL. They first watched selected trainee 'anchor' video performances and scored them independently. Next, the raters compared scores and discussed all discrepancies until consensus was reached.

rating a group of 30 videos. Intraclass correlation coefficients (ICC) (two-way mixed model) were calculated to assess the inter-rater reliability of these post-calibration training ratings provided by the two examiners. Single measures ICC for the GRS (0.79) and CL (0.75) demonstrated substantial agreement (0.61-0.80) according to the guidelines suggested by Landis and Koch (1977) and as a result, the remaining 240 videos were divided equally and scored independently by the two raters.

ICSAD Hand Motion Efficiency – Time And Hand Movements. The same variables (total time and number of hand movements) that were extracted from ICSAD in Study 1 were also used for this study.

Suturing Performance Interpretation. The ICSAD measures in conjunction with the expert assessment scores (GRS and CL) were used to assess overall suturing performance. The ICSAD measures have been validated against the GRS and CL (Datta et al., 2001; Datta et al., 2002; Dumestre et al., 2014; Jowett et al., 2007). Fewer hand movements and time to completion for the ICSAD measures and higher scores on the GRS and CL scales depicted superior suturing performance.

3.3.5 – *Data Analyses*[19]

Psychological Measures

Motivational Profile. SIMS and SISE were analyzed in the same manner as in Study 1.

Task-Specific Self-Efficacy. The self-efficacy data for the simple interrupted suture (baseline task), horizontal mattress suture (learning task), and corner stitch suture (transfer test) were each analyzed using the same approach that was used in Study 1.

Mental Demand, Effort, Performance, Frustration. The simple interrupted suture, horizontal mattress suture, and corner stitch suture data for the NASA-TLX measures of interest (mental demand, effort, performance, and frustration) were each analyzed using the same approach that was used in Study 1.

Behavioural Measures

Expert Assessment – Global Rating Scale And Checklist. Although the individual components of the GRS and CL are ordinal in nature (Likert scales), the overall scores of the GRS and CL behave empirically as a parametric variable (Carifio & Perla, 2008) and were therefore, analyzed using parametrical statistics (Brydges, Carnahan, Backstein, & Dubrowski, 2007; Carifio & Perla, 2008; Gonzalez et al., 2011; Martin et al., 1997; Norman, 2010; Walsh et al., 2011). The simple interrupted suture data and the corner stitch suture data for the GRS and

[19] The analyses used for the suturing portion found in the preceding chapter (Chapter 2) were the same analyses used for this study however; this present study also included expert assessment measures (i.e., GRS and CL).

CL scores were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last factor. The horizontal mattress suture data for the GRS and CL scores were each analyzed using a 3 (social-comparative feedback group: Positive, Negative, Control) x 3 (test: pre-practice, post-practice, retention) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last two factors.

ICSAD Hand Motion Efficiency – Time And Hand Movements. The simple interrupted suture, horizontal mattress suture, and corner stitch suture data for the ICSAD measures of interest (time, number of hand movements) were each analyzed using the same approach that was used in Study 1.

3.4 – RESULTS[20]

Psychological Measures

Motivational Profile. Descriptive statistics (shown in Table 3.1) suggest that the trainees recruited for this study represent a subset of highly-motivated participants, which is in line with previous research (Ferguson et al., 2002; Hutchins, 1964; Kusurkar et al., 2011; Mattick & Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner & Nicholson, 2011). Analyses for each subscale of the SIMS (intrinsic motivation, identified regulation, external regulation and amotivation) and the SISE scale

[20] For all effects, associated means and standard deviations are reported in Tables 3.1 and 3.2.

revealed no significant baseline group differences for both (state) motivation and (trait) self-esteem.

Task-Specific Self-Efficacy. Analysis of the self-efficacy ratings for the simple interrupted suture (baseline task) revealed no significant baseline group differences[21]. Analysis of the self-efficacy ratings for the horizontal mattress suture task (learning task) revealed a significant main effect for group, $F(2, 27) = 6.60$, $p = .005$, $\eta_p^2 = .328$. Post-hoc analysis revealed that the NF group reported significantly lower self-efficacy ratings than the PF group (M = 55% compared to M = 72%, respectively). Analysis of the self-efficacy ratings for the corner stitch suture task (transfer task) revealed a significant main effect for group, $F(2, 27) = 5.52$, $p = .010$, $\eta_p^2 = .290$. Post-hoc analysis revealed that the NF group reported significantly lower self-efficacy ratings (M = 48%) than the PF and CF groups (M = 71% and M = 64%, respectively). (See Figure 3.7).

Mental Demand, Effort, Performance, Frustration. Analysis of each NASA-TLX variable (mental demand, effort, performance, frustration) for both the simple interrupted (baseline task) and corner stitch suture (transfer task) revealed no significant group differences. Analysis of the mental demand, effort and frustration ratings data for the horizontal mattress suture task (learning task) revealed a significant main effect for test: mental demand, $F(1, 27) = 10.93$, $p = .003$, $\eta_p^2 = .288$; effort, $F(1, 27) = 7.97$, $p = .009$, $\eta_p^2 = .228$; frustration, $F(1, 27)$

[21] Baseline self-efficacy ratings revealed no significant group differences ($p = .159$), however the baseline score for the PF group was much lower than the NF and CF groups. Therefore, this warranted the analyses to be repeated using the baseline self-efficacy scores as a covariate in the ANCOVA. The ANCOVA analyses for both the retention and transfer data did not change the reported ANOVA findings.

= 4.39, p = .046, η_p^2 = .140. Post-hoc analyses revealed that trainees rated their mental demand significantly lower for the horizontal mattress suture performed during the second session compared to the first (M = 58% compared to M = 69%), their effort significantly lower in the second session for the horizontal mattress suture compared to the first (M = 60% compared to M = 70%), and their frustration significantly lower in the second session for the horizontal mattress suture compared to the first (M = 36% compared to M = 43%). There were no main effects found for group or interactions. Analysis of performance rating data for the horizontal mattress suture revealed no main effects for group or test, or interaction.

Behavioural Measures

Expert Assessment – Global Rating Scale.[22] Analysis of the GRS baseline data (simple interrupted suture) revealed no main effect for group or trial, or interaction. Analysis of the GRS retention data (horizontal mattress suture) revealed a significant main effect for group, $F(2, 26) = 3.74$, p = .037, η_p^2 = .224. Post-hoc analysis revealed that the NF group had significantly lower GRS scores compared to the PF and CF groups (M = 12.87 compared to M = 15.39 and M = 15.48, respectively). There was also a significant main effect for test, $F(2, 52)$ = 4.66, p = .014, η_p^2 = .152, which showed that trainees had significantly lower GRS scores on the first horizontal mattress suture test (M = 13.69) compared to

[22] All GRS ratings for 1 trainee in the NF group were excluded from analyses (due to technical issues with video recordings, 6 out of the 9 trials for this trainee were unable to be scored by the two raters). Therefore, GRS ratings on only 29 trainees were included in the final analyses.

the second (M = 14.99) and final (M = 15.06)[23]. Additionally, there was a main effect found for trial, $F(1, 26) = 9.99$, $p = .004$, $\eta_p^2 = .278$. Post-hoc analysis revealed that trainees scored significantly lower on the first trial (M = 13.83) compared to the second trial (M = 15.33). No interactions were revealed. The NF group struggled particularly under the following GRS categories: 'flow of the operation' and 'overall performance'. Analysis of the GRS transfer data (corner stitch suture) revealed no main effect for group or trial, or interaction. (See Figure 3.6).

Expert Assessment – Checklist.[24] Analysis of the CL baseline data (simple interrupted suture) revealed no main effect for group or trial, or interaction. Analysis of the CL retention data (horizontal mattress suture) revealed a significant main effect for group, $F(2, 26) = 5.19$, $p = .013$, $\eta_p^2 = .285$. Post-hoc analysis revealed that the NF group had significantly lower CL scores compared to the PF and CF groups (M = 6.40 compared to M = 7.23 and M = 7.27). There was no main effect for test or trial, and no interactions found. Analysis of the CL transfer data (corner stitch suture task) revealed a significant main effect for group, $F(2, 26) = 3.43$, $p = .048$, $\eta_p^2 = .209$. Post-hoc analysis revealed that the NF group had significantly lower CL scores compared to the PF group (M = 7.10 compared to M = 8.30, respectively). (See Figure 3.5).

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[23] The first and second horizontal mattress test (each consisting of two trials) was completed during the first testing session, while the final horizontal mattress test was completed during the second session.

[24] All CL ratings for 1 trainee in the NF group were excluded from analyses (due to technical issues with video recordings, 6 out of the 9 trials for this trainee were unable to be scored by the two raters). Therefore, CL ratings on only 29 trainees were included in the final analyses.

ICSAD Hand Motion Efficiency – Time. Analysis of the total task time baseline data (simple interrupted suture) revealed a significant main effect for time, $F(1, 27) = 26.97$, $p < .001$, $\eta_p^2 = .500$, where trainees performed the first trial significantly slower (M = 156 s) than the second trial (M = 136 s). Baseline total time scores revealed no significant group differences ($p = .063$), however this was approaching conventional levels of significance and the baseline total time score for the NF group was much higher (M = 163 s) than the PF and CF groups (M = 137 s and M = 136 s, respectively). Therefore, this warranted the initial ANOVAs to be repeated using the baseline total task time scores as a covariate in the ANCOVAs (for both the retention and transfer data). The results of both analyses (no covariate and with a covariate) are outlined below (also see Figure 3.4).

ANOVA (no covariate) for the retention data: Analysis of the total task time retention data (horizontal mattress suture task) revealed a significant main effect for group, $F(2, 27) = 3.95$, $p = .031$, $\eta_p^2 = .226$. Post-hoc analysis revealed that the NF group took significantly longer (M = 228 s) to complete the task compared to the PF and CF groups (M = 177 s and M = 174 s, respectively). There was also a significant interaction for trial x test, $F(2, 54) = 5.00$, $p = .012$, $\eta_p^2 = .156$, where post-hoc analysis revealed that the PF and CF trainees had more stable performance (in terms of the total task time variable) from the second horizontal mattress test (consisting of two horizontal mattress sutures performed at the end of *Session 1*) to the third test (consisting of two horizontal mattress sutures performed as the retention test completed during *Session 2*) (M = 161 s on the second test to M = 164 s on the third test, aggregated across both PF and CF groups) compared to the NF trainees who demonstrated an increase (M = 201 s on the second test to M = 218 s on the third test) in the amount of total time to perform the horizontal mattress suturing techniques. The source of the interaction is based on the differences being larger and more negative (i.e., an increase in total time) between the PF and CF groups in comparison to the NF group following a 48-hour delay. There was also a significant main effect for trial, $F(1, 27) = 37.15$, $p < .001$, $\eta_p^2 = .579$, and test, $F(2, 54) = 33.32$, $p < .001$, $\eta_p^2 = .552$. No other interactions were found. $F(2, 27) = 3.95$, $p = .031$, $\eta_p^2 = .226$.

ANCOVA (with baseline simple interrupted total time scores as a covariate) for the retention data: With the baseline simple interrupted total time scores used as the covariate, the main effect for group was no longer significant, $F(2, 26) = .757$, $p = .479$, $\eta_p^2 = .050$. The ANCOVA analysis did not change the other results reported above (i.e., the trial by test interaction and the main effect for trial and test).

ANOVA (no covariate) for the transfer data: Analysis of the total task time transfer data for the corner stitch suture task revealed an effect approaching conventional levels of significance for the main effect of group, $F(2, 27) = 2.71$, $p = .084$, $\eta_p^2 = .167$, with the NF group taking longer (M = 194 s) to complete the corner stitch suture compared to the PF and CF groups (M = 163 s and M = 163 s, respectively).

ANCOVA (with baseline simple interrupted total time scores as a covariate) for the transfer data: The ANCOVA analysis did not change the results.

ICSAD Hand Motion Efficiency – Hand Movements. Analysis of the hand movements baseline data (simple interrupted suture task) revealed a significant main effect for time, $F(1, 27) = 8.69$, $p = .007$, $\eta_p^2 = .243$, where trainees made more hand movements on the first trial (M = 108 hand movements) compared to the second trial (M = 97 hand movements). Baseline hand movement scores for the simple interrupted suture revealed no significant group differences ($p = .060$), however this was approaching conventional levels of significance and the baseline hand movement score for the NF group was much higher (M = 113 hand movements) than the PF and CF groups (M = 100 hand movements and M = 95 hand movements, respectively). Therefore, this warranted the initial ANOVAs to be repeated using the baseline hand movement scores as a covariate in the ANCOVAs (for both the retention and transfer data). The results of both analyses are outlined below (also see Figure 3.3).

ANOVA (no covariate) for the retention data: Analysis of the hand movement retention data (horizontal mattress suture task) revealed a significant main effect for group, $F(2, 27) = 3.45$, $p = .046$, $\eta_p^2 = .204$. Post-hoc analysis revealed that the NF group had made significantly more hand movements (less efficient) (M = 156 hand movements) compared to the CF group (M = 122 movements). There was a significant main effect for trial, $F(1, 27) = 15.31$, $p =$

.001, $\eta_p^2 = .362$, where trainees made significantly more hand movements on the first trial (M = 143 hand movements) compared to the second trial (M = 130 movements). There was also a significant main effect for test, $F(2, 54) = 19.21$, $p < .001$, $\eta_p^2 = .416$, where trainees made significantly more hand movements on the first horizontal mattress test (M = 151 hand movements) compared to the other two tests (M = 129 movements on the second test and M = 130 movements on the final test). No interactions were found.

ANCOVA (with baseline simple interrupted hand movement scores as a covariate) for the retention data: With the baseline simple interrupted hand movement scores used as the covariate, the main effect for group was no longer significant, $F(2, 26) = .707$, $p = .503$. The ANCOVA analysis did not change the other results reported above (i.e., the main effect for trial and test).

Analysis of the hand movement transfer data (corner stitch suture) revealed no main effect for group (both using ANOVA and ANCOVA analyses).

Self-Regulatory Techniques During Suturing Practice[25]

There were no group differences in how frequently the training videos were watched during practice as well as the number of sutures thrown (for both the simple interrupted and horizontal mattress suture).

Suturing Learning Strategies

The NF group reported using primarily different strategies *during* suturing to help them perform and learn the suturing techniques compared to both the PF

[25] See Table 3.2 for specific details.

and CF groups, which reported using primarily different strategies *prior* to suturing performance (see Table 3.2 for details).

Anecdotal reports from the trainees also demonstrated the extent to which the negative social-comparative feedback influenced their mindsets throughout the testing sessions compared to those trainees receiving positive social-comparative feedback (see below).

Negative Social-Comparative Feedback Group: *'I didn't do too well', 'not looking forward to surgical rotations', 'surgery is definitely not for me', 'can suture someone up but it wouldn't be too pretty', 'not the best at this kind of stuff', 'surgery isn't my area', 'feedback made me nervous', 'it's because I'm feeling tired'*

Positive Social-Comparative Feedback Group: *'feedback boosted my confidence', 'validation that I was performing better than others and the right steps, especially as a beginner', 'I shouldn't rule out surgery', 'not expert yet but better than others', 'I was dreaming about suturing last night'*

3.5 – DISCUSSION

The purpose of this study was to extend our previous work (Study 1, Chapter 2) to a more clinically-relevant context because it is important to understand the feedback scenarios that medical students are receiving during their training (mainly social comparative feedback and related to specific clinical skills) as well as the different contexts in which this type of feedback could be potentially harmful to trainees. Based on our previous findings (Study 1), we expected that providing novice medical trainees with positive social-comparative feedback during the learning of a suturing task would not provide additional benefits for technical skill acquisition compared to a control condition receiving no social-comparative feedback. Similarly, we also expected that providing negative social-comparative feedback would be detrimental for the learning process. Consistent with our hypotheses, positive social-comparative feedback did not facilitate learning and negative social-comparative feedback was detrimental to performance and learning when compared to a no-feedback condition. Novice medical trainees receiving negative social-comparative feedback also experienced unfavourable effects to their self-efficacy beliefs. Additionally, anecdotal reports from these trainees revealed the extent to which the negative social-comparative feedback influenced their mindsets throughout the testing sessions compared to trainees in the other two groups.

In this study, the delivery frequency of the fabricated feedback was lower compared to the previous study (i.e., twice instead of seven times). The reduction in the feedback delivery instances was implemented in this study specifically to better mimic an authentic clinical feedback encounter. It is not realistic for a trainee to receive seven instances of feedback during one learning opportunity in a clinical setting, as in the case of Study 1. Nevertheless, the delivery of negative social-comparative feedback, now reduced in frequency, was again detrimental to the learning process and potent enough to alter expert assessment (ratings on the GRS and CL) of technical skill performance. In our previous work (Study 1), the higher frequency of positive social-comparative feedback that trainees received already prior to the suturing task (on a less relevant computer key-pressing task) caused them to choose not to watch the expert suture training videos during practice – perhaps creating a false sense of confidence and/or not wanting to show the experimenter that they had to re-watch the suturing videos (e.g., two trainees in the PF group apologized for having to re-watch parts of the videos). In this study however, the majority of the trainees (see Table 3.2) watched the training videos while they practiced the suturing techniques (i.e., simple interrupted and horizontal mattress suture). Interestingly, although the negative social-comparative feedback altered self-efficacy ratings and was detrimental to suturing performance, the initial feedback manipulation prior to the first suturing technique did not modify how practice was self-regulated[26] (i.e., the watching of the training videos and the lack of group differences found for the number of sutures that were completed during practice). This could have been due to the lower frequency of false social-comparative feedback that was delivered.

Generally, the affective consequences of receiving negative social-comparative feedback (even twice as per this present study) impacted how the feedback was internalized and responded to. Typically for learners that are highly-motivated, like the novice medical trainees in this study, receiving information (i.e., below-average feedback) that conflicts with their self-perceptions will create a negative psychological state of discomfort (termed 'dissonance') (Aronson, 1968, 1992, 1999; Festinger, 1957). There is evidence that highly-motivated learners in this case would experience a more adverse emotional reaction to dissonance and as a result would be more intensely driven to reduce this

[26] This was in contrast to the findings of the previous study where the delivery of negative social-comparative feedback altered the number of sutures that trainees completed during practice for the initial suturing task (i.e., they completed fewer simple interrupted sutures compared to trainees in the PF and CF groups).

discrepancy (Frey, 1986; Harmon-Jones, 2012, Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2011). This body of evidence is in line with our findings as well as the other work that is conducted in medical education to try to understand the emotional process/reaction that is triggered by receiving negative feedback. The effects of negative feedback on trainees can have long-lasting adverse consequences that are difficult to ignore and require a rather lengthy reflective process to aid with coping (Sargeant et al., 2005; Sargeant et al., 2008). Just as in Study 1 (Chapter 2), this emotional reaction could be shifting attention during the learning process (Brand et al., 2007; Easterbrook, 1959; Ellsworth & Scherer, 2003; Frijda, 1993; Kluger & DeNisi, 1996; LeBlanc et al., 2015; McConnell & Eva, 2012; Moors et al., 2013; Smallwood et al., 2007; Smallwood & Schooler, 2006). Evidence for this from our current study includes the pattern of attentional shifts with respect to the performance and learning strategies that the NF trainees reported before they were debriefed. For instance, all NF trainees reported that they employed strategies only *during* the actual suturing tasks (e.g., step rehearsal while they were performing the technique); whereas, most trainees in the PF and CF groups reported strategies that they employed *prior* to performing the technique (e.g., rehearsing the steps of the suture before performing it).

The methodological changes that were implemented and findings of this study are both relevant to feedback delivery in a clinical context. We demonstrate that the provision of a below-average mindset in novice medical trainees is sensitive to gold standard clinical measures of technical skill assessment (expert ratings on the GRS and CL). Our findings help address Lefroy and colleagues (2015) concerns regarding the unknown effects that social feedback may have in clinical education. The results of this research (this study and Study 1) demonstrate that when below-average feedback is provided to novice medical trainees, it is detrimental to them on both a psychological and behavioural level. Our results have significant implications for feedback delivery in medical education. They also provide insight into puzzling results that Harrison and colleagues (2013) found. In this study, medical trainees were provided with web-based access to an extensive personalized performance feedback summary, which included various social-comparative feedback metrics, following an objective structural clinical examination (OSCE) that they had performed (Harrison et al., 2013). Interestingly, the low achieving students (i.e., the ones who had just barely passed the examination) made the least use of this feedback. For example, these trainees accessed the web-based feedback the least, even though they could have benefitted the most from receiving a detailed report regarding their performance. Based on our research (this study and Study 1), we suggest that the presence of social-comparative feedback (in this case, below-average feedback) may be contributing to the lack of feedback-seeking behaviour that Harrison and colleagues (2013) found for the low achieving trainees. Perhaps the delivery of social-comparative feedback was unintentionally creating harm, at the very least on a psychological level (in the form of dissonance).

This study contributes to an emerging line of research (Study 1, Chapter 2) demonstrating that medical trainees, a subset of highly-motivated learners, interpret social-comparative feedback differently than other learners studied in the literature (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2016) and have particular difficulty in receiving information that they are performing worse than their peers. One of the limiting factors in our research is that the fabricated social-comparative feedback that we provided medical trainees in both studies was regardless of their actual performance, whereas other research exploring normative feedback tends to provide the social-comparative manipulation by exaggerating a participant's actual performance score (Avila et al., 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010). For example, a participant would receive his or her actual score and then the fabricated social-comparative feedback would be calculated as a certain percentage above or below this score, depending on group assignment (e.g., 20% above to indicate to the participant that he/she is performing below average). However, due to the nature of our experimental design in addition to concerns about potential contamination (fabricated feedback being provided to a close-knit group of medical students), we chose to provide the same group average information to all trainees. Another limitation of our research is related to the source of the feedback in both of our studies (this study and Study 1). Medical trainees may have interpreted the negative social-comparative in a detrimental manner compared to other learners in the literature because the feedback they were receiving was from a hypothetical 'expert'. As a result, this caveat is addressed in following study (Study 3, Chapter 4). Based on these findings, we recommend future research not only continue to explore what characteristics constitute effective feedback but we urge research, particularly in clinical education, to try to also better understand potential consequences of using specific types of feedback (e.g., social-comparative feedback) and why some types of feedback (e.g., negative social-comparative feedback) is being internalized in a manner that is detrimental to the learning process in medical trainees.

3.6 – FIGURE AND TABLE APPENDIX

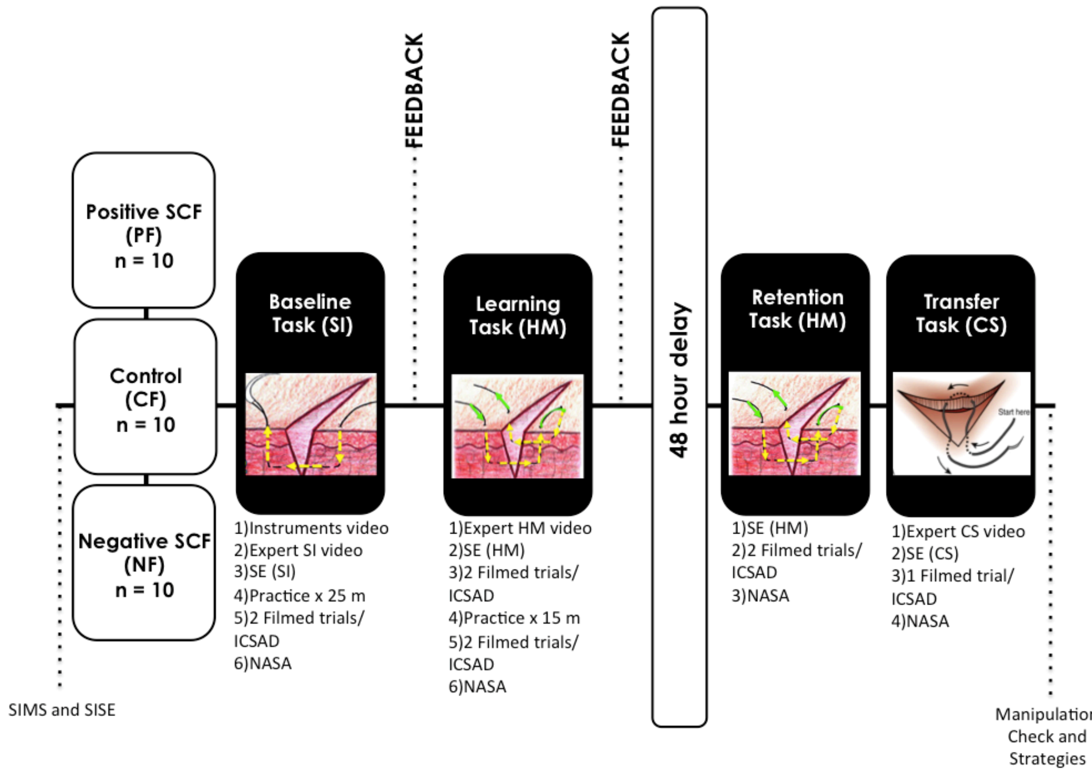

Figure 3.1. Experimental design for Study 2.
Note. SIMS = situational motivational scale; SISE = single-item self-esteem scale; SE = self-efficacy; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index; ICSAD = Imperial College Surgical Assessment Device

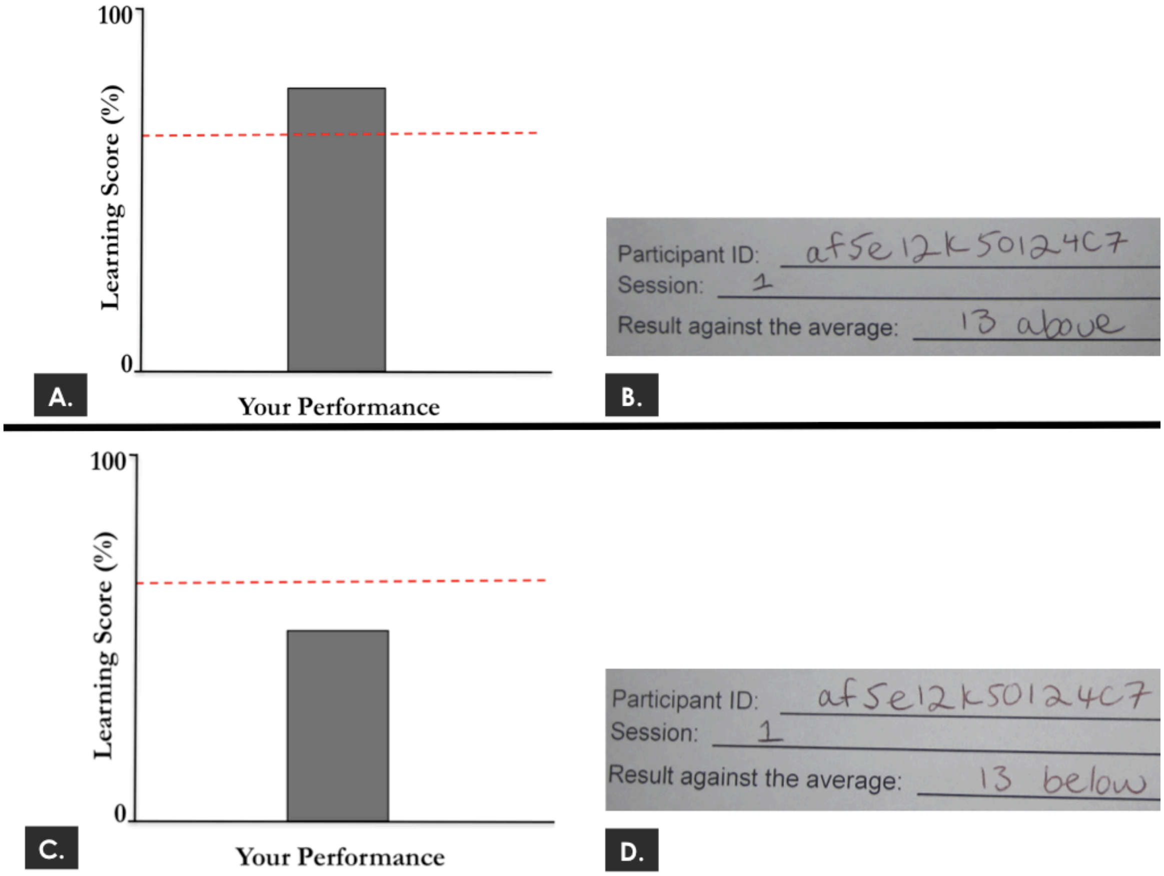

Figure 3.2. An example of the performance summaries that the PF and NF trainees received during the suturing acquisition phase. These performance summaries were provided following the simple interrupted suture and at the end of practice for the horizontal mattress suture. **A.** An example of a performance summary provided to the PF trainees following performance of the simple interrupted suture, which indicates that the trainee performed the technique above the average; **B.** An example of a performance summary provided to the PF trainees following performance of the horizontal mattress suture, which indicates that the trainee performed the technique above the average; **C.** An example of a performance summary provided to the NF trainees following performance of the simple interrupted suture, which indicates that the trainee performed the technique below the average; **D.** An example of a performance summary provided to the NF trainees following performance of the horizontal mattress suture, which indicates that the trainee performed the technique below the average.

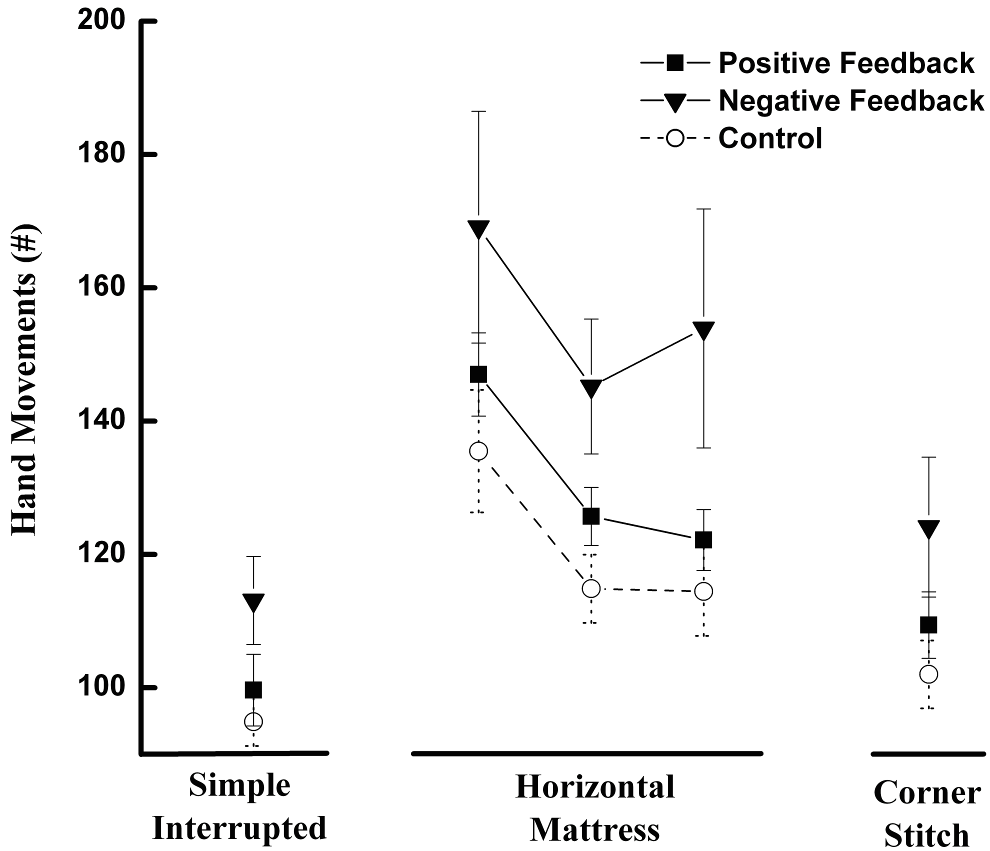

Figure 3.3. Number of Hand Movements (ICSAD measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (48 hours later). Error bars represent standard error of the mean.

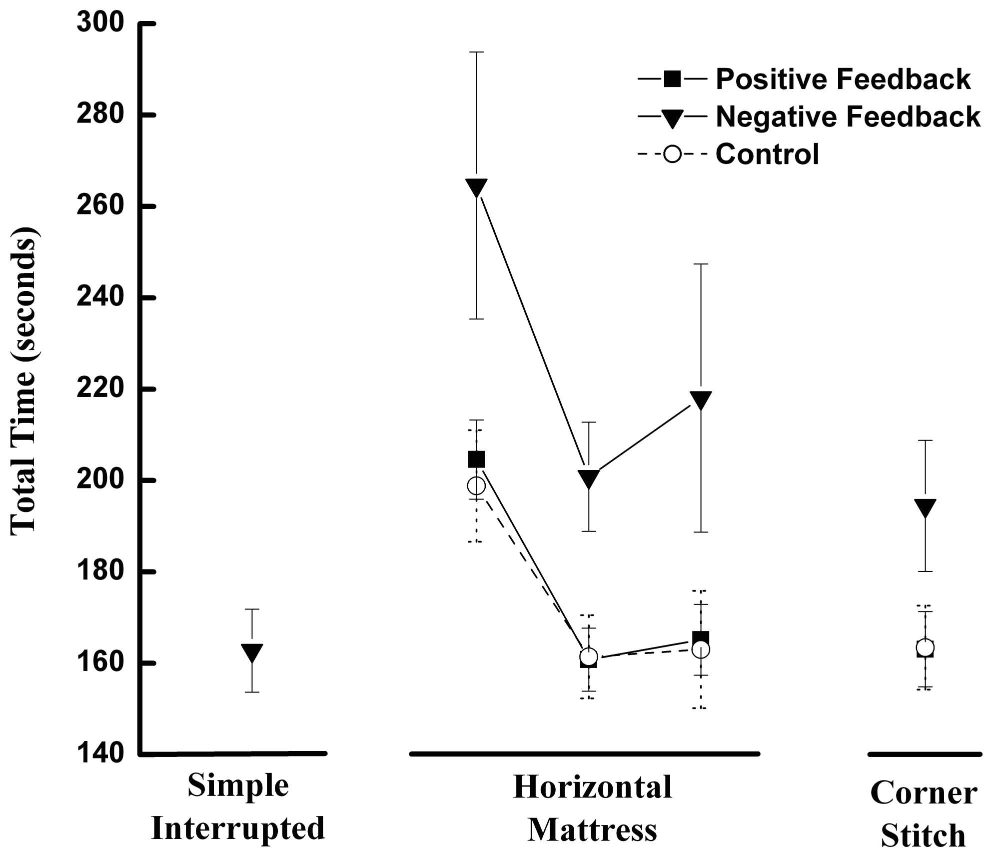

Figure 3.4. Total (suture) Time (ICSAD measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (48 hours later). Error bars represent standard error of the mean.

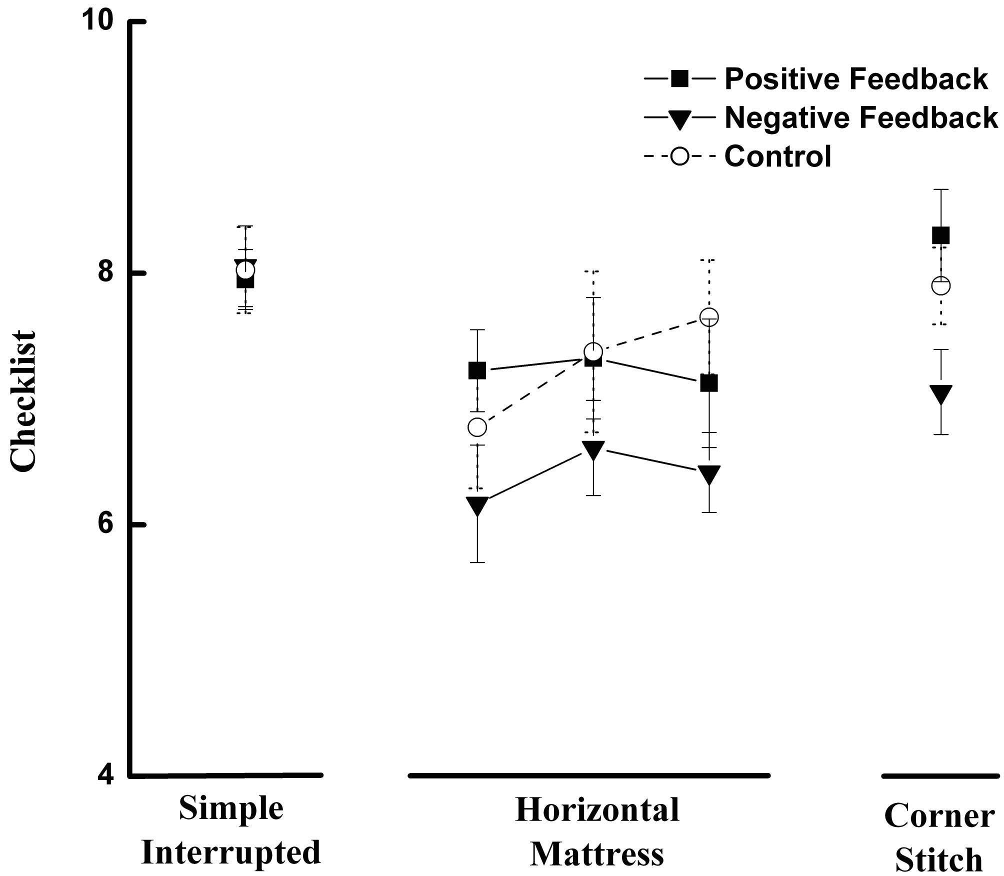

Figure 3.5. Suturing-specific Checklist (CL) score (Expert assessment measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (48 hours later). Error bars represent standard error of the mean.

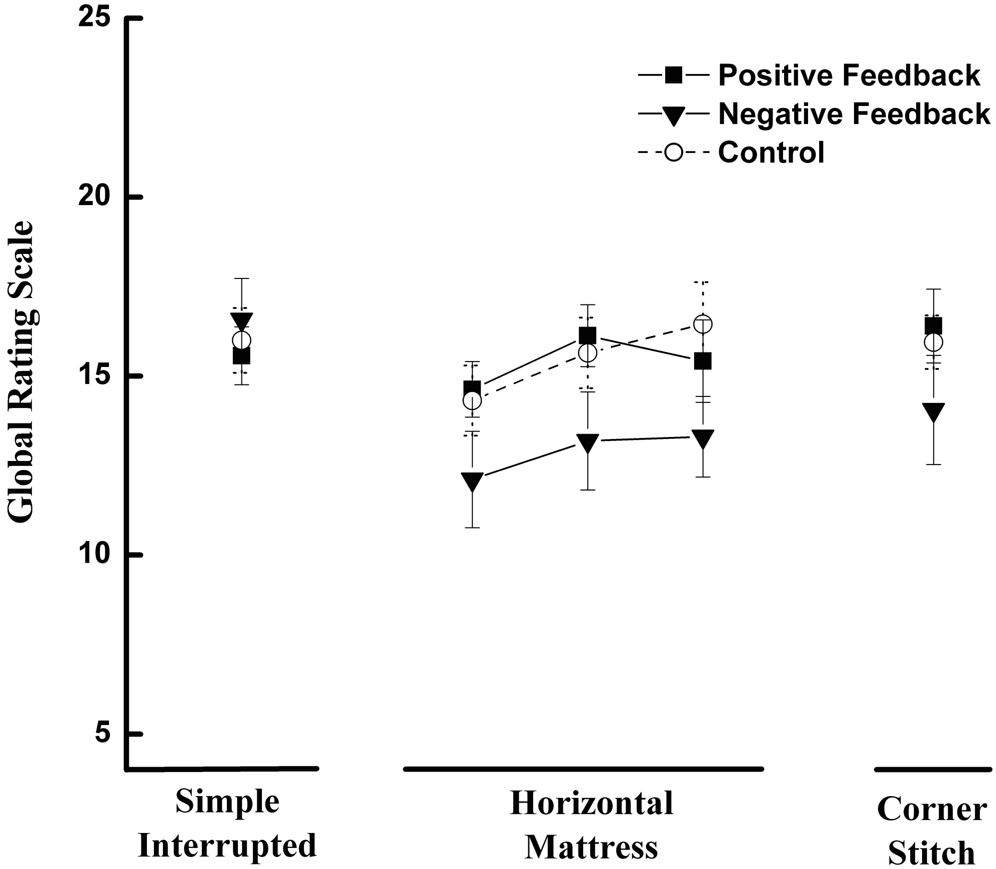

Figure 3.6. Suturing-specific Global Rating Scale (GRS) score (Expert assessment measure) for PF, NF, and CF groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (48 hours later). Error bars represent standard error of the mean.

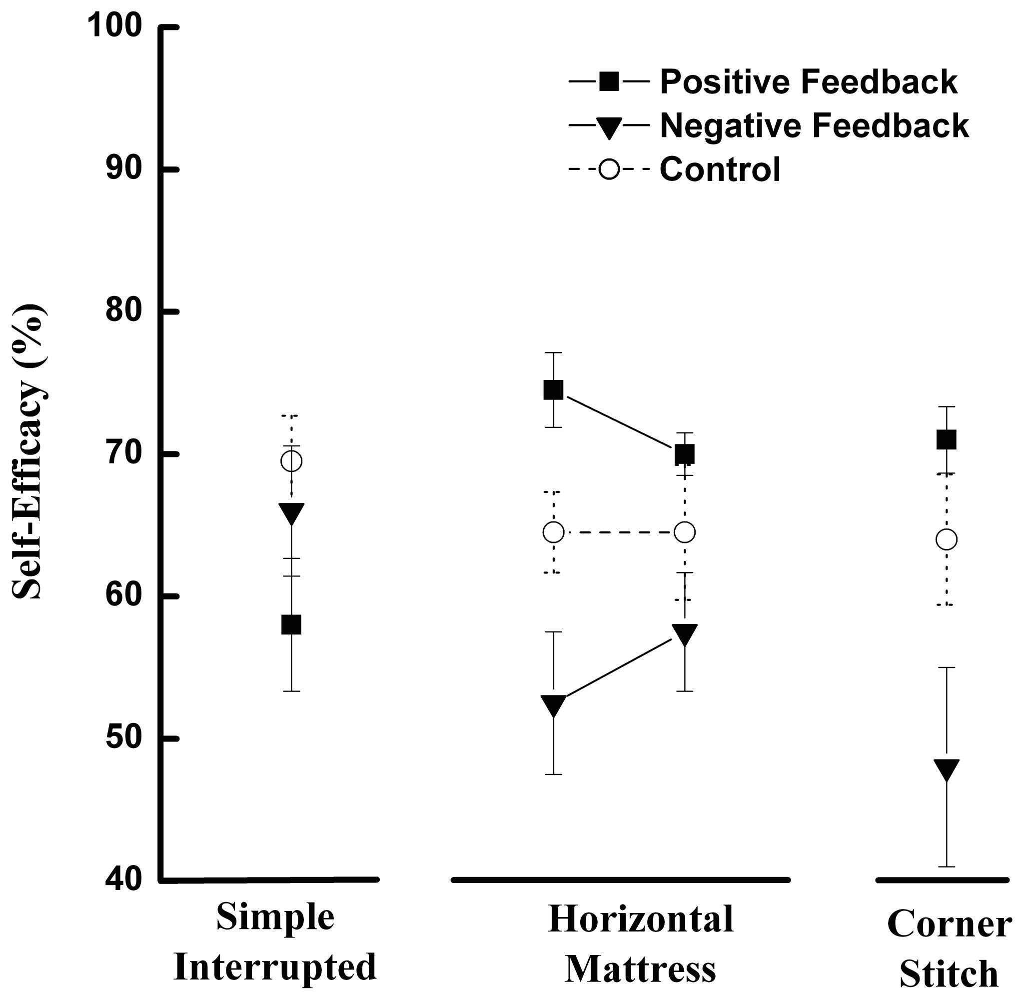

Figure 3.7. Suturing self-efficacy ratings for the PF, NF, and CF groups prior to performing the simple interrupted suture and the horizontal mattress suture during *Session 1* and prior to performing the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (48 hours later). Error bars represent standard error of the mean.

Table 3.1: Participant demographics and psychological ratings

	Positive Social-Comparative Feedback (PF) n=10 *M* (*SD*)		Negative Social-Comparative Feedback (NF) n=10 *M* (*SD*)		Control (CF) n=10 *M* (*SD*)	
Age	23.9	(2.7)	24.2	(2.3)	24.3	(1.9)
Situational Motivation (7-pt scale)						
Intrinsic Motivation	5.0	(0.6)	4.9	(0.8)	5.2	(0.6)
Identified Regulation	5.7	(0.6)	5.9	(0.7)	6.1	(0.6)
External Regulation	2.1	(1.3)	2.8	(1.2)	2.3	(0.7)
Amotivation	1.6	(0.6)	1.9	(0.6)	1.9	(0.9)
Global Self-esteem (5-pt scale)	3.8	(0.8)	4.4	(0.5)	3.9	(0.6)
Suturing: Importance (/100%)	88.0	(13.2)	76.0	(15.8)	85.0	(12.7)
Suturing: Self-efficacy (/100%)						
SI	58.0	(14.8)	66.0	(14.5)	69.5	(10.1)
HM Acquisition	74.5	(8.3)	52.5	(15.9)	64.5	(9.0)
HM Retention	70.0	(4.7)	57.5	(13.2)	64.5	(15.0)
CS	71.0	(7.4)	48.0	(22.1)	64.0	(14.5)
SI: NASA (/100%)						
Mental Demand	67.0	(20.0)	72.0	(16.9)	56.5	(15.3)
Effort	76.5	(12.9)	72.0	(13.2)	70.5	(11.2)
Performance	58.0	(14.8)	50.0	(20.0)	62.5	(16.2)
Frustration	38.5	(20.0)	50.5	(18.9)	35.0	(15.1)
HM Acquisition: NASA (/100%)						
Mental Demand	68.5	(22.9)	75.0	(17.2)	62.5	(19.3)
Effort	71.5	(21.1)	72.0	(21.0)	67.5	(19.3)
Performance	62.0	(14.0)	47.0	(23.6)	65.0	(23.2)
Frustration	42.5	(22.0)	50.5	(15.7)	37.0	(18.9)
HM Retention: NASA (/100%)						
Mental Demand	59.0	(24.2)	60.0	(19.4)	55.0	(23.2)
Effort	61.5	(25.2)	62.0	(19.3)	56.0	(21.2)
Performance	63.0	(20.0)	55.5	(17.4)	69.5	(15.0)
Frustration	32.0	(24.9)	39.0	(18.5)	37.0	(24.1)
CS: NASA (/100%)						
Mental Demand	67.5	(16.2)	63.0	(23.1)	63.0	(24.1)
Effort	68.0	(18.3)	59.0	(21.3)	62.0	(21.0)
Performance	59.5	(15.4)	50.0	(9.4)	62.5	(19.3)
Frustration	37.0	(19.5)	39.0	(21.3)	31.5	(18.6)

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

Table 3.2: Participant behavioural outcomes on suturing

	Positive Social-Comparative Feedback (PF) n=10 *M* (*SD*)		Negative Social-Comparative Feedback (NF) n=10 *M* (*SD*)		Control (CF) n=10 *M* (*SD*)	
Suturing trials: Total Time						
SI trial 1	147.0	(20.8)	173.1	(32.5)	147.9	(34.2)
SI trial 2	127.6	(16.4)	152.3	(30.0)	129.1	(29.2)
HM1 trial 1	219.2	(24.2)	281.4	(117.0)	218.2	(55.5)
HM2 trial 1	164.9	(19.2)	197.5	(41.6)	171.8	(33.9)
HM3 trial 1	175.4	(29.9)	240.5	(100.1)	173.9	(43.6)
HM1 trial 2	190.0	(40.3)	247.8	(72.6)	179.4	(23.7)
HM2 trial 2	156.7	(27.9)	204.1	(37.9)	151.1	(29.5)
HM3 trial 2	154.9	(25.1)	195.6	(90.6)	152.1	(39.1)
CS trial 1	163.1	(26.0)	194.4	(45.4)	163.4	(29.1)
Suturing trials: Hand Movements						
SI trial 1	106.0	(19.8)	118.5	(24.2)	100.3	(8.2)
SI trial 2	93.3	(17.0)	107.7	(26.2)	89.5	(19.2)
HM1 trial 1	150.2	(19.7)	172.9	(60.4)	150.0	(49.0)
HM2 trial 1	128.8	(17.8)	142.9	(40.0)	123.2	(22.0)
HM3 trial 1	128.0	(17.7)	166.5	(66.8)	120.7	(23.9)
HM1 trial 2	143.8	(29.2)	165.3	(55.8)	121.0	(13.7)
HM2 trial 2	122.6	(16.8)	147.5	(27.5)	106.5	(15.7)
HM3 trial 2	116.3	(15.7)	141.3	(57.6)	108.2	(19.9)
CS trial 1	109.4	(15.7)	124.1	(33.2)	102.0	(16.1)
Suturing trials: Global Rating Scale (out of 25)						
SI trial 1	15.9	(2.9)	16.7	(4.1)	16.4	(2.2)
SI trial 2	15.3	(2.2)	16.5	(2.8)	15.6	(3.5)
HM1 trial 1	13.6	(2.9)	12.0	(5.2)	13.4	(3.7)
HM2 trial 1	15.7	(2.1)	12.2	(2.9)	15.3	(2.5)
HM3 trial 1	16.1	(2.4)	13.3	(4.5)	14.8	(2.6)
HM1 trial 2	16.1	(3.1)	13.1	(3.8)	16.5	(3.7)
HM2 trial 2	14.3	(3.5)	12.0	(3.7)	15.1	(4.2)
HM3 trial 2	16.5	(3.8)	14.6	(3.0)	17.9	(3.3)
CS trial 1	16.4	(3.3)	14.1	(4.6)	15.9	(2.4)
Suturing trials: Checklist (out of 10)						
SI trial 1	8.1	(0.9)	8.1	(0.9)	8.0	(1.2)
SI trial 2	7.8	(0.6)	8.0	(1.0)	8.1	(1.0)
HM1 trial 1	6.8	(1.3)	5.8	(1.6)	6.4	(1.6)
HM2 trial 1	7.7	(0.7)	6.6	(1.2)	7.2	(1.5)
HM3 trial 1	7.3	(1.6)	6.6	(1.1)	7.2	(1.9)
HM1 trial 2	7.3	(1.4)	6.6	(1.2)	7.6	(2.1)
HM2 trial 2	6.8	(1.4)	6.1	(1.1)	7.3	(1.5)
HM3 trial 2	7.4	(1.8)	6.8	(0.8)	7.9	(1.4)
CS trial 1	8.3	(1.2)	7.1	(1.0)	7.9	(1.0)
Practice sutures: Total Number						
SI (in 25m)	6.5	(1.1)	6.2	(1.4)	6.0	(1.1)
HM (in 15m)	3.6	(1.1)	3.3	(0.7)	3.5	(0.7)
Number of participants who watched video during practice						
SI	10/10	-	10/10	-	8/10	-
HM	9/10	-	10/10	-	9/10	-
Number of participants that adopted specific strategies related to performing suturing techniques						
Strategies before task	9/10	-	0/10	-	8/10	-
Strategies during task	1/10	-	10/10	-	1/10	-
Strategies before and during task	0/10	-	0/10	-	1/10	-

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; HM1 = first set of horizontal mattress sutures completed during *Session 1*; HM2 = second set of horizontal mattress sutures completed during *Session 1*; HM3 = third set of horizontal mattress sutures completed during *Session 2*; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

CHAPTER 4:

THE INFLUENCE OF THE FEEDBACK PROVIDER ON A MEDICAL TRAINEE'S MINDSET DURING PROCEDURAL SKILL ACQUISITION

4.1 – ABSTRACT

Our previous research (Study 2, Chapter 3) suggests that medical trainees, irrespective of the task (Study 1, Chapter 2), respond differently to social-comparative feedback than other types of learners. Positive social-comparative feedback did not facilitate technical skill acquisition compared to a control condition receiving no feedback; whereas, novice medical trainees who were provided with feedback indicating that they were performing worse than the group average on a baseline surgical task (regardless of their actual performance) experienced significant detriments to self-efficacy, performance and learning of a new suturing technique. However, one caveat was that the fabricated information was always delivered from the same type of feedback provider (a hypothetical clinician) and could provide further insight into why trainees interpreted the negative social-comparative feedback in a manner contrary to previous research. This study examined whether the credibility of the feedback provider played a role in how social-comparative feedback was being internalized by novice medical trainees. Since effective feedback must be derived from a credible source (Bandura, 1997; Bannister, 1986; Eagly & Himmelfarb, 1978; Ilgen et al., 1979; Latting, 1992; Maddux, 2002), we hypothesized that trainees who received social-comparative feedback from a clinician (an expert) compared to a peer (a novice) would be more influenced by the "more credible" feedback (as determined by psychological and behavioural measures). Following a baseline surgical skill acquisition session, novice medical trainees were randomly assigned to one of

four conditions, where they received manipulated information to suggest that either a clinician or another peer rated their performance as being better or worse than the average, regardless of how they actually performed the surgical techniques. The findings revealed that regardless of who the feedback provider was (clinician versus another peer), the *experience* of receiving negative social-comparative feedback impacted self-reported psychological measures and the immediate performance of a basic surgical technique. These findings are important in the context of feedback delivery and remediation as they provide further evidence that novice medical trainees experience difficulty in receiving information that they are performing relatively poorly compared to their peers.

4.2 – INTRODUCTION

Our previous research (Study 1, Chapter 2; Study 2, Chapter 3) seems to suggest that medical trainees, regardless of the task (Study 1, Chapter 2), may interpret social-comparative feedback differently than do other types of learners (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2010, 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2016). Contrary to the research in the motor learning domain, our findings demonstrate that positive social-comparative feedback did not facilitate technical skill acquisition compared to a control condition receiving no feedback; whereas, novice medical trainees who were provided with feedback indicating that they were performing worse than the group average on a baseline surgical task (regardless of their actual performance) experienced significant detriments to self-efficacy, performance and learning of a new suturing technique. However, one caveat in our previous work was that the manipulated social-comparative feedback was always being delivered from a hypothetical clinical 'expert'. There is an extensive body of literature that suggests the credibility of the feedback provider (expertise, reputability and trustworthiness) (Bandura, 1997; Eagly & Himmelfarb, 1978; Latting, 1992; Maddux, 2002) will be given more weight by the receiver. Furthermore, expert credibility is judged more critically than other sources (Watling et al., 2012), and if the feedback 'persuader' is perceived by the receiver as being credible, powerful and trustworthy then this feedback will more likely be accepted as well as interpreted as being accurate (Bannister, 1986; Ilgen et al., 1979; Latting, 1992). Perhaps the fabricated negative social-comparative feedback that was delivered in our previous studies was being interpreted in a detrimental manner (contrary to previous research exploring this type of feedback in other learners) because it was coming from an 'expert'. Therefore, the purpose of this study was to further investigate this caveat by manipulating the source of the feedback in order to determine how the nature of the feedback provider would influence feedback interpretation in novice medical trainees during the learning process.

Feedback interactions in clinical education are diverse. Trainees can receive feedback from many sources other than a clinical expert, including a fellow peer or a patient (Archer, 2010; Lefroy et al., 2015). Since peer learning and assessments have been increasingly incorporated into the medical curricula, we chose for the other source of feedback in this present study to be a hypothetical 'peer' (de la Cruz, Kopec, & Wimsatt, 2015; Snydman, Chandler, Rencic, & Sung, 2013). There has been a push to use peer-to-peer assessments because it is less resource-intensive and trainees receive more feedback throughout their training. Peer feedback has also been viewed as being rewarding (both to deliver and receive) (Snydman et al., 2013). This is a major benefit since there have been many reports that medical trainees are not satisfied with the quantity or quality of feedback that they receive during their training (Bing-You & Trowbridge, 2009; Cantillon & Sargeant, 2008; Delva et al., 2013; Gil et al., 1984; Isaacson et al., 1995; Kogan et al., 2000; Robins et al., 1997; Sumit et al., 2004). Peer-to-peer feedback can even lead to feedback exchanges that entail more specific corrective feedback (Chou, Masters, Chang, Kruidering, & Hauer, 2013). Perhaps negative social-comparative feedback would not be as harmful to internalize if it was being received from a fellow peer. This could even dampen the detrimental effects of negative social-comparative feedback that we found in our previous work (Study 1, Chapter 2; Study 2; Chapter 3).

Therefore, our goal for this study was to determine whether the credibility of the feedback provider (expert versus peer) played a role in how social-comparative feedback was being internalized by novice medical trainees.

Based on our previous findings (Study 1 and Study 2), we predicted that novice medical trainees receiving false negative social-comparative feedback (expert and peer) compared to positive social-comparative feedback would experience detriments to their learning of surgical techniques. We also expected that based on the literature (Bandura, 1997; Bannister, 1986; Eagly & Himmelfarb, 1978; Ilgen et al., 1979; Latting, 1992; Maddux, 2002), social-comparative feedback (positive and negative) delivered from a hypothetical 'expert' would be perceived as being more 'credible' compared to the feedback from a hypothetical 'peer', and as a result would have a greater influence on the learning process.

4.3 – METHODS

4.3.1 – *Participants*

Forty-four novice pre-clerkship (years 1 and 2) medical trainees (29 female) with a mean age of 23.30 (*SD* = 2.33) from the University of Toronto participated in this study. Ethics approval was obtained from the home institutional site (i.e., McMaster University, #2012187) as well as the data collection site (i.e., University of Toronto, #28391). Data collection consisted of two sessions separated by 24 hours, for a total time commitment of approximately three hours. Each trainee was compensated 20 dollars upon study completion (*Session 1* and *2*).

Just as in Study 1 (Chapter 2) and Study 2 (Chapter 3), we wanted to confirm that the recruited trainees were in fact a subset of highly-motivated learners. As a result, prior to data collection, we had all trainees complete the SIMS (Guay et al., 2000) and SISE (Robins et al., 2001) scales as a baseline measure of learner motivation (see Table 4.1 for specific values).

Trainees were randomly assigned to one of four groups[27], where during ***Session 2***[28] the:

<u>Positive Clinician social-comparative feedback group (pCL)</u>: received **positive** social-comparative feedback from a hypothetical '**Clinician**' regarding their ***Session 1*** performance of the horizontal mattress suture task;

<u>Positive Trainee social-comparative feedback group (pTR)</u>: received **positive** social-comparative feedback from a hypothetical '**Trainee**' regarding their ***Session 1*** performance of the horizontal mattress suture task;

[27] Based on the findings in Study 1 and 2, the two positive social-comparative feedback groups in this study (i.e., pCL and pTR) served as the control conditions.

[28] No experimental manipulation occurred during *Session 1*.

Negative Clinician social-comparative feedback group (nCL): received **negative** social-comparative feedback from a hypothetical '**Clinician**' regarding their ***Session 1*** performance of the horizontal mattress suture task;

Negative Trainee social-comparative feedback group (nTR): received **negative** social-comparative feedback from a hypothetical '**Trainee**' regarding their ***Session 1*** performance of the horizontal mattress suture task.

4.3.2 – *Experimental Apparatus And Task*

The suturing task (i.e., the acquisition of three suturing techniques: simple interrupted suture, horizontal mattress suture, and corner stitch suture) and the apparatus (i.e., ICSAD) used in this study were identical to what was used in Study 1 (the suturing portion of Chapter 2) and Study 2 (Chapter 3).

The presentation of the fabricated social-comparative feedback however, differed when compared to Study 1 and Study 2. Specifically, *all* trainees in this study received some form of fabricated social-comparative feedback. Furthermore, the feedback manipulation in this study occurred only once, and the fabricated social-comparative feedback (from a hypothetical 'clinician' or 'peer') was delivered during *Session 2*[29] via an online educational-networking platform, *Observational Practice and Educational Networking* (OPEN)[30]. OPEN is a completely secure educational-networking system that was developed in 2010 as a platform for health professions education research projects aiming to understand

[29] No feedback manipulation occurred during *Session 1*. Therefore, *Session 1* essentially served as a control session.

[30] OPEN is a collaborative effort between the University of Toronto and the University of Ontario Institute of Technology.

features of collaborative learning and computer-based instructional design (via online). OPEN was also designed to allow users to access, share, and interact with different clinically-relevant content, and receive or provide feedback (anonymously or not) (Grierson, Barry, Kapralos, Carnahan, & Dubrowski, 2012; Rojas et al., 2012). In 2015, OPEN was re-developed (Khan, 2015) from using Web 2.0 to using the open-source Django framework (Threespot & Andrevv, 2005-2016) and the Model View Controller design pattern. The feedback and quiz features of OPEN were customized by Zain Khan to be used for this study. OPEN can be accessed using the following IP address: http://199.212.33.115:8003/.

Specific methodological modifications that were made will be described next.

4.3.3 – *Experimental Protocol*[31]

The experimental protocol for all trainees during *Session 1* was identical (no feedback manipulation occurred during this session). Following the completion of the *Session 1* tasks, all trainees were introduced to the OPEN platform. To encourage authenticity, each trainee created his or her own username, password, and profile (see Figure 4.2 B). Trainees were then enrolled in a suturing course where they watched and rated one suturing video using the GRS and CL scales built into the system. Trainees were led to believe that the suturing video they were asked to rate was of one of their peers who were also

[31] Experimental protocol was identical to the one used in Study 1 (the suturing portion in Chapter 2) and Study 2 (Chapter 3) with the exception of the following details: the presentation, timing, and frequency of the social-comparative feedback. Figure 4.1 illustrates a schematic of the experimental design.

participating in the study. Instead trainees all rated the same video, which featured the primary investigator completing a horizontal mattress suture[32] (Figure 4.2 A). The suturing performance in this video aimed to mimic novice performance and incorporate some common errors. Once trainees finished scoring the video using the GRS and CL, they were informed that their videos would be uploaded into the OPEN system. Trainees were also led to believe that depending on resources available, their *Session 1* suturing performance would be scored by either a clinician or a fellow peer on both the GRS and CL.

Trainees returned after a 24-hour delay for *Session 2*, where they first used their existing username and password to log back into OPEN. They were then able to access their performance feedback (fabricated) from the previous session. All trainees received social-comparative feedback regarding their combined GRS and CL performance of the horizontal mattress suture (same suture that they scored in the previous session). Specifically, trainees in the pCL and pTR groups received feedback that they were '14% above average' as rated by a 'clinician' or another 'trainee', respectively. The trainees in the nCL and nTR groups received feedback that they were '14% below average' as rated by a 'clinician' or another 'trainee', respectively (see Figure 4.2 B for an example of the feedback provided to a trainee in the nCL group).

[32] The primary investigator was trained by a surgical fellow to perform the suturing technique.

To assess the performance (not learning[33]) effect of the feedback manipulation, trainees then reported their self-efficacy for performing the horizontal mattress technique before actually performing two separate trials of this suture. They used the NASA-TLX to rate their filmed horizontal mattress performance. Trainees then watched the corner stitch instructional video, before attempting one trial (video and ICSAD) of this brand new suturing technique (Figure 2.7 C from Chapter 2), to measure the effect of feedback on skill transfer (near transfer task). They again used the NASA-TLX to rate their filmed performance (for the corner stitch). At the end of this session a manipulation check was done to ensure that trainees believed the fabricated feedback (i.e., 'how do you feel you performed during your last session')[34]. Trainees were then debriefed[35] on the true nature of the experiment as well as asked to re-consent to the experimental protocol. All trainees were also provided with the option to receive their actual performance scores post data collection.

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[33] Trainees learned the horizontal mattress suture technique during *Session 1* where there was no feedback manipulation provided and therefore the acquisition process was not experimentally altered. Instead, due to the design of this study, the fabricated feedback was aimed to modify psychological and behavioural outcomes *after* acquisition. Therefore, due to the timing of the feedback manipulation, our outcome measures assessed the influence of the feedback manipulation on the performance (and not learning) of the horizontal mattress.

[34] Prior to being debriefed, participants were also asked a few informal questions regarding their interpretation of the feedback and various features of the feedback provider. These responses are currently being analyzed.

[35] The debriefing session ensured that trainees understood that the feedback they had received during the experiment was entirely manipulated by the experimenters and did not at all reflect their actual performance and ability to learn the suturing techniques.

4.3.4 – *Outcome Measures*[36]

Psychological Measures

Motivational Profile. SIMS (Guay et al., 2000) and SISE (Robins et al., 2001) scales that were used in Study 1 and 2 were also used in this study. Internal consistency for each subscale of SIMS in this study was as follows: intrinsic motivation Cronbach's $\alpha = .85$, identified regulation Cronbach's $\alpha = .76$, external regulation Cronbach's $\alpha = .76$, amotivation Cronbach's $\alpha = .70$. According to Nunnally and Bernstein's guidelines (1994), internal consistency for all subscales is considered to acceptable.

Task-Specific Self-Efficacy. Self-reported self-efficacy that was used in Study 1 and 2 was also used in this study.

Mental Demand, Effort, Performance, Frustration. Self-reported mental demand, effort, performance and frustration subscales from the NASA-TLX questionnaire (Hart & Staveland, 1988) that were used in Study 1 and 2 were also used in this study.

Behavioural Measures

ICSAD Hand Motion Efficiency – Time And Hand Movements. The same variables (total time and number of hand movements) that were extracted from ICSAD in Study 1 and 2 were also used for this study.

[36] The outcome measures (psychological and behavioural) used in this present study are identical to those used in Study 1 (the suturing portion in Chapter 2) and Study 2. The videos in this study have also been prepared to undergo expert assessment (using the GRS and CL): however, at the time that this document was being prepared, these sets of analyses are still in-progress.

4.3.5 – *Data Analyses*[37]

Psychological Measures

Motivational Profile. SIMS and SISE were analyzed in the same manner as in Study 1 and 2.

Task-Specific Self-Efficacy. The self-efficacy data for all the suturing techniques were each analyzed using 2 (feedback: Positive, Negative) x 2 (provider: Clinician, Trainee) one-way ANOVAs.

Mental Demand, Effort, Performance, Frustration. The NASA-TLX measures of interest (mental demand, effort, performance, frustration) for all the suturing techniques were each analyzed using 2 (feedback: Positive, Negative) x 2 (provider: Clinician, Trainee) one-way ANOVAs.

Behavioural Measures

ICSAD Hand Motion Efficiency – Time And Hand Movements. The simple interrupted suture data for the ICSAD measures of interest (time, number of hand movements) were each analyzed using a 2 (feedback: Positive, Negative) x 2 (provider: Clinician, Trainee) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last factor. The horizontal mattress suture acquisition data for the ICSAD measures of interest (time, number of hand movements) were each analyzed using a 2 (feedback: Positive, Negative) x 2 (provider: Clinician, Trainee) x 2 (test: pre-practice, post-practice) x 2 (trial: trial 1, trial 2) mixed ANOVA with repeated measures on the last two factors. Since the feedback

[37] The analyses were modified in order to align with the methodological changes that were made to this study (e.g., the timing of the feedback manipulation and the 2x2 design).

delivery in this study occurred only once, following the suturing acquisition phase (i.e., Session 2), and the feedback content that was delivered was very subtle; we expected that the second trial would not be impacted by the feedback manipulation. Furthermore, we predicted that the inclusion of trial 2 would mask the subtlety of the feedback effects, and therefore we made the decision to conduct the horizontal mattress retention data and corner stitch data on only the first trial post-feedback manipulation. The horizontal mattress suture retention data and the corner stitch suture transfer data (only the first trial) for the ICSAD measures of interest (time, number of hand movements) were therefore each analyzed using 2 (feedback: Positive, Negative) x 2 (provider: Clinician, Trainee) one-way ANOVAs.

4.4 – RESULTS[38]

Psychological Measures

Motivational Profile. Descriptive statistics (shown in Table 4.1) suggest that the trainees recruited for the study have characteristics of highly-motivated learners, which is in line with our findings in Study 1 (Chapter 2) and Study 2 (Chapter 3) as well as with previous research (Ferguson et al., 2002; Harrison et al., 2013; Hutchins, 1964; Kusurkar et al., 2011; Mattick & Knight, 2009; Moulaert et al., 2004; Sobral, 2004; Tanaka et al., 2009; Todisco et al., 1995; Turner & Nicholson, 2011). Analyses for each subscale of the SIMS (intrinsic motivation, identified regulation, external regulation and amotivation) and the

[38] For all effects, associated means and standard deviations are reported in Tables 4.1 and 4.2.

SISE scale revealed no significant baseline group differences for both (state) motivation and (trait) self-esteem.

Task-Specific Self-Efficacy. Analysis of the self-efficacy ratings for the simple interrupted suture and the *Session 1* horizontal mattress suture (both completed during *Session 1* and representing baseline tasks) revealed no significant baseline group differences for either the feedback (positive or negative) or provider (clinician or trainee). Analysis of the self-efficacy ratings for the *Session 2* horizontal mattress suture task (completed post-manipulation) revealed a significant main effect for feedback, $F(1, 40) = 5.78$, $p = .021$, $\eta_p^2 = .126$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) reported significantly lower self-efficacy ratings (M = 57%) than positive social-comparative feedback groups (pCL and pTR) (M= 69%). No main effect was found for the feedback provider (clinician or trainee). Analysis of the self-efficacy ratings for the corner stitch suture revealed no main effects of feedback or provider. (See Figure 4.7).

Mental Demand, Effort, Performance, Frustration. Analysis of each NASA-TLX variable (mental demand, effort, performance, frustration) for both the simple interrupted suture and the *Session 1* horizontal mattress suture revealed no significant differences for main effects of feedback or provider. Analysis of the mental demand and effort variables for the *Session 2* horizontal mattress suture also revealed no main effects of feedback or provider. Analysis of the performance ratings data for the *Session 2* horizontal mattress suture (completed post-manipulation) revealed a significant main for feedback, $F(1, 40) = 14.91$, $p < .001$, $\eta_p^2 = .272$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) reported significantly lower performance ratings (M = 50%) than positive social-comparative feedback groups (pCL and pTR) (M = 68%). No main effect was found for the feedback provider (clinician or trainee). Analysis of the frustration ratings data for the *Session 2* horizontal mattress suture (completed post-manipulation) revealed a significant main for feedback, $F(1, 40) = 5.80$, $p = .021$, $\eta_p^2 = .127$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) reported significantly higher frustration ratings (M = 50%) than positive social-comparative feedback groups (pCL and pTR) (M = 34%). No main effect was evident for the feedback provider (clinician or trainee) (See Figure 4.5). Analysis of the mental demand, effort and frustration rating variables for the corner stitch suture revealed no main effects of feedback or provider. Analysis of the performance transfer data (corner stitch suture task) revealed a significant main effect for feedback, $F(1, 40) = 7.85$, $p = .008$, $\eta_p^2 = .164$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) rated their performance significantly lower (M = 43%) than the positive social-comparative feedback groups (pCL and pTR) (M = 60%). No main effect was found for the feedback provider (clinician or trainee) (See Figure 4.6).

Behavioural Measures

ICSAD Hand Motion Efficiency – Time. Analysis of the total task time baseline data (simple interrupted suture task) revealed a significant main effect for trial, $F(1, 40) = 41.68$, $p < .001$, $\eta_p^2 = .510$, where trainees performed the first trial significantly slower (M = 191 s) than the second trial (M = 156 s). No main effect was found for group nor was there an interaction of group and trial. Analysis of the total task time baseline data (pre- and post-practice horizontal mattress suture completed during Session 1) revealed a significant main effect for test, $F(1, 40) = 84.29$, $p < .001$, $\eta_p^2 = .678$. Post-hoc analysis revealed that trainees took significantly more time to complete the pre-practice horizontal mattress suture (M = 245 s) compared to the post-practice horizontal mattress suture (M = 213 s). There was also a significant main effect for trial, $F(1, 40) = 77.76$, $p < .001$, $\eta_p^2 = .660$, where trainees took significantly longer to complete the first trial (M = 248 s) compared to the second trial (M = 210 s) of the horizontal mattress suture completed during *Session 1*. There were no main effects found for feedback and provider, or interactions. Analysis of the total task time post-manipulation data (first trial only of the *Session 2* horizontal mattress suture) revealed a significant main effect for feedback, $F(1, 40) = 4.18$, $p = .047$, $\eta_p^2 = .095$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) took significantly longer to complete the horizontal mattress suture on the first trial post-manipulation (M = 230 s) compared to the positive social-comparative feedback groups (pCL and pTR) (M = 201 s). Main effects found for test, trial, and provider, or interactions were not found. Analysis of the total task time post-manipulation corner stitch data (first trial only) revealed no main effects of feedback or provider. (See Figure 4.4).

ICSAD Hand Motion Efficiency – Hand Movements. Analysis of the hand movements baseline data (simple interrupted suture task) revealed a significant main effect for trial, $F(1, 40) = 12.80$, $p = .001$, $\eta_p^2 = .242$, where trainees performed the first trial with significantly more hand movements (M = 154 hand movements) than the second trial (M = 138 hand movements). No main effect was found for group or interaction. Analysis of the hand movements baseline data (pre- and post-practice horizontal mattress suture completed during Session 1) revealed a significant main effect for test, $F(1, 40) = 36.45$, $p < .001$, $\eta_p^2 = .477$. Post-hoc analysis revealed that trainees made significantly more hand movements on the pre-practice horizontal mattress suture test (M = 200 hand movements) compared to the post-practice horizontal mattress suture test (M = 177 hand movements). There was also a significant main effect for trial, $F(1, 40) = 34.67$, $p < .001$, $\eta_p^2 = .464$, where trainees made significantly more hand movements on the first trial (M = 198 hand movements) compared to the second trial (M = 179 hand movements) of the horizontal mattress suture completed during *Session 1*. There were no main effects for feedback or provider, or interactions. Analysis of the hand movements post-manipulation data (first trial only of the *Session 2* horizontal mattress suture) revealed a significant main effect for feedback, $F(1, 40) = 4.92$, $p = .032$, $\eta_p^2 = .109$. Post-hoc analysis revealed that the negative social-comparative feedback groups (nCL and nTR) made significantly more hand movements on the first trial (post-manipulation) for the horizontal mattress suture (M = 197 hand movements) compared to the positive social-comparative feedback groups (pCL and pTR) (M = 175 hand movements). Main effects found for test, trial, and provider, or interactions were not found. Analysis of the hand movements post-manipulation corner stitch data (first trial only) revealed no main effects of feedback or provider. (See Figure 4.3).

Self-Regulatory Techniques During Suturing Practice[39]

There were no group differences in how much the training videos were watched during practice as well as the number of sutures thrown (for both the simple interrupted and horizontal mattress suture).

Suturing Learning Strategies

Similar to Study 1 and Study 2, there was a trend for the negative social-comparative feedback groups (nCL and nTR) in this study to use strategies that were more directed towards the suturing task while it was being performed compared to the trainees in the other two groups (pCL and pTR), who reported using strategies primarily *prior* to suturing performance (see Table 4.2 for details).

4.5 – DISCUSSION

Our previous work (Study 2, Chapter 3) demonstrated that novice medical trainees, irrespective of the motor task (Study 1, Chapter 2), interpret social-

[39] See Table 4.2 for specific details.

comparative feedback differently than other types of learners studied in the literature (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2010, 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2016). This difference in feedback interpretation and internalization could have been due to who provided the feedback. For instance, in our previous research the fabricated information was always delivered from the same type of feedback provider (a hypothetical clinician) and this could provide further insight into why novice trainees interpreted the negative social-comparative feedback in a manner that was contrary to previous research. As a result, the purpose of this study was to manipulate the *source* of the feedback to determine whether the credibility of the feedback provider (expert versus peer) would influence how novice medical trainees were internalizing social-comparative feedback during technical skill acquisition.

Our findings suggest that regardless of who the feedback provider was (clinician versus trainee), the *experience* of receiving negative social-comparative feedback impacted psychological measures and the immediate performance of a surgical technique (i.e., horizontal mattress suture). More specifically, when trainees (nCL and nTR) received negative social-comparative feedback[40] regarding their horizontal mattress suture performance from the previous testing session, they experienced immediate performance detriments when having to again perform this suturing technique during *Session 2* (i.e., took significantly

[40] Social-comparative feedback was only delivered once during *Session 2* (24 hours later).

longer to complete the technique and made more hand movements while performing it). In addition, trainees in the nCL and nTR conditions reported significantly lower self-efficacy and performance ratings, and higher levels of frustration related to performing this technique immediately following feedback manipulation. Our findings suggest that there was no carry-over effect (psychological and behavioural) to the new suturing technique (corner stitch) with the exception of self-reported performance (the nCL and nTR groups reported significantly lower performance ratings for the corner stitch suture; however, no actual performance changes were evident). There was also a trend starting to emerge for the negative social-comparative feedback groups (nCL and nTR) to use strategies that were more directed towards the suturing task while it was being performed. This was not the case for the trainees in the other two groups (pCL and pTR), who reported using strategies primarily *prior* to suturing performance (see Table 4.2 for details). However, the strategy shifts in the negative social-comparative feedback groups (nCL and nTR) were not as prominent as in Study 1 and Study 2. This could have been due to the timing and frequency of the social-comparative feedback that was implemented in this study where the feedback manipulation occurred only once during *Session 2*.

The findings of this study also provide some initial suggestion that peer feedback can be used as a method for providing trainees with more performance information during their training without compromising feedback 'quality' (i.e., our results suggest that peer feedback was not perceived to be 'less influential' than expert feedback). However, if the feedback provider (expert or peer) delivers negative social-comparative feedback then this information alone (regardless of the feedback source) could hinder psychological and behavioural outcomes. Moreover, our results suggest that social-comparative feedback is working at a level independent of the feedback provider, and that the *experience* of receiving below-average feedback is potent enough to alter the trainee's mindset and behaviour. This contradicts a robust line of research that suggests expert feedback is perceived to be more influential as a tool for behavioural change (Bandura, 1997; Bannister, 1986; Eagly & Himmelfarb, 1978; Ilgen et al., 1979; Latting, 1992; Maddux, 2002). However, this could be due to the trainees not forming a relationship with the 'feedback provider' (which is a key requirement in the development of trust and credibility). Moreover, the feedback delivered was both vague and subtle. On the other hand, it is surprising that one instance of this feedback was potent enough to elicit psychological and behavioural changes in the medical trainees (nCL and nTR groups). Future work should explore other feedback sources (patients, anonymous raters, examiners) to better understand how the feedback provider might influence the learning process in novice medical trainees. Not only has there been a recent initiative towards peer assessment in clinical education but there is also an initiative towards multi-source feedback (MSF) (Sargeant et al., 2008), with the rationale that trainees receiving more perspectives (i.e., more data points) will have a better understanding of their performance. However, MSF interventions currently lack robust evidence to indicate that they offer an added benefit to the learner (Violato, Lockyer, & Fidler, 2008). In summary, we need to better understand the complexities involved in feedback interactions and what makes feedback meaningful to the receiver before investing costly resources that may not provide additional learning benefits.

Our work provides evidence that the delivery of negative social-comparative feedback, regardless of the provider, is detrimental to novice medical trainees both on a psychological and behavioural level. Furthermore, our findings are important in the context of feedback delivery and remediation as they provide further evidence that novice medical trainees experience difficulty in receiving information that they are performing relatively poorly compared to their peers. Future research needs to understand why medical trainees internalize below-average feedback in a manner that is detrimental for skill acquisition and create interventions in order to help trainees cope with the reality of receiving this type of feedback.

4.6 – FIGURE AND TABLE APPENDIX

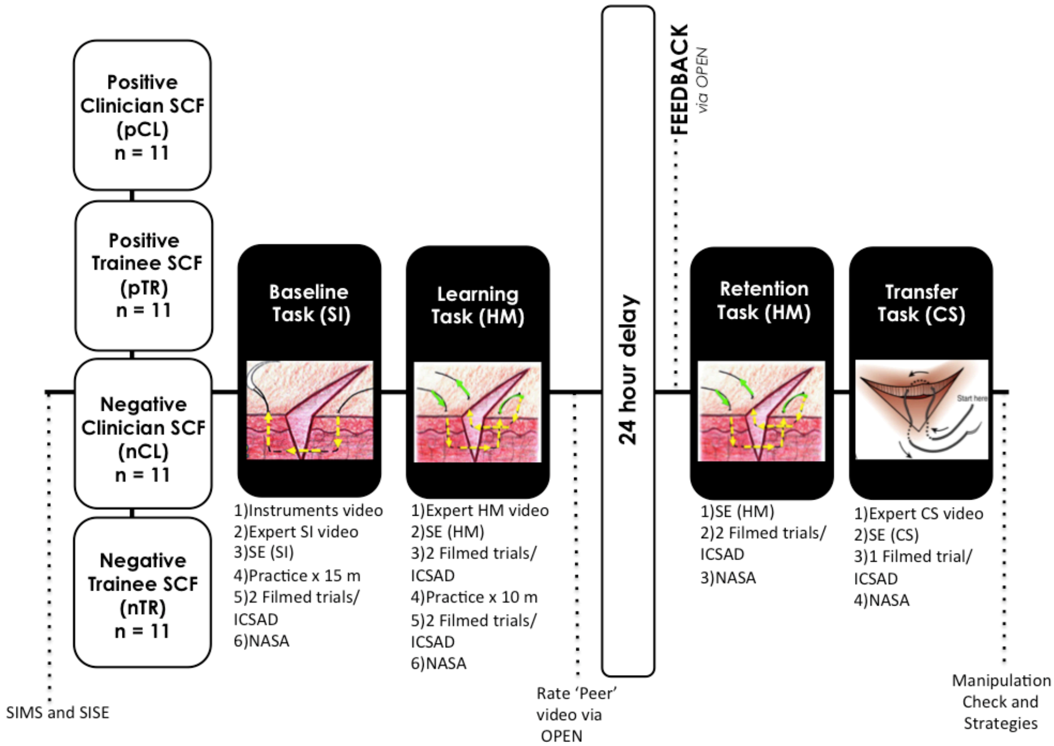

Figure 4.1. Experimental design for Study 3.
Note. SIMS = situational motivational scale; SISE = single-item self-esteem scale; SE = self-efficacy; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index; ICSAD = Imperial College Surgical Assessment Device; OPEN = Observational Practice and Educational Networking

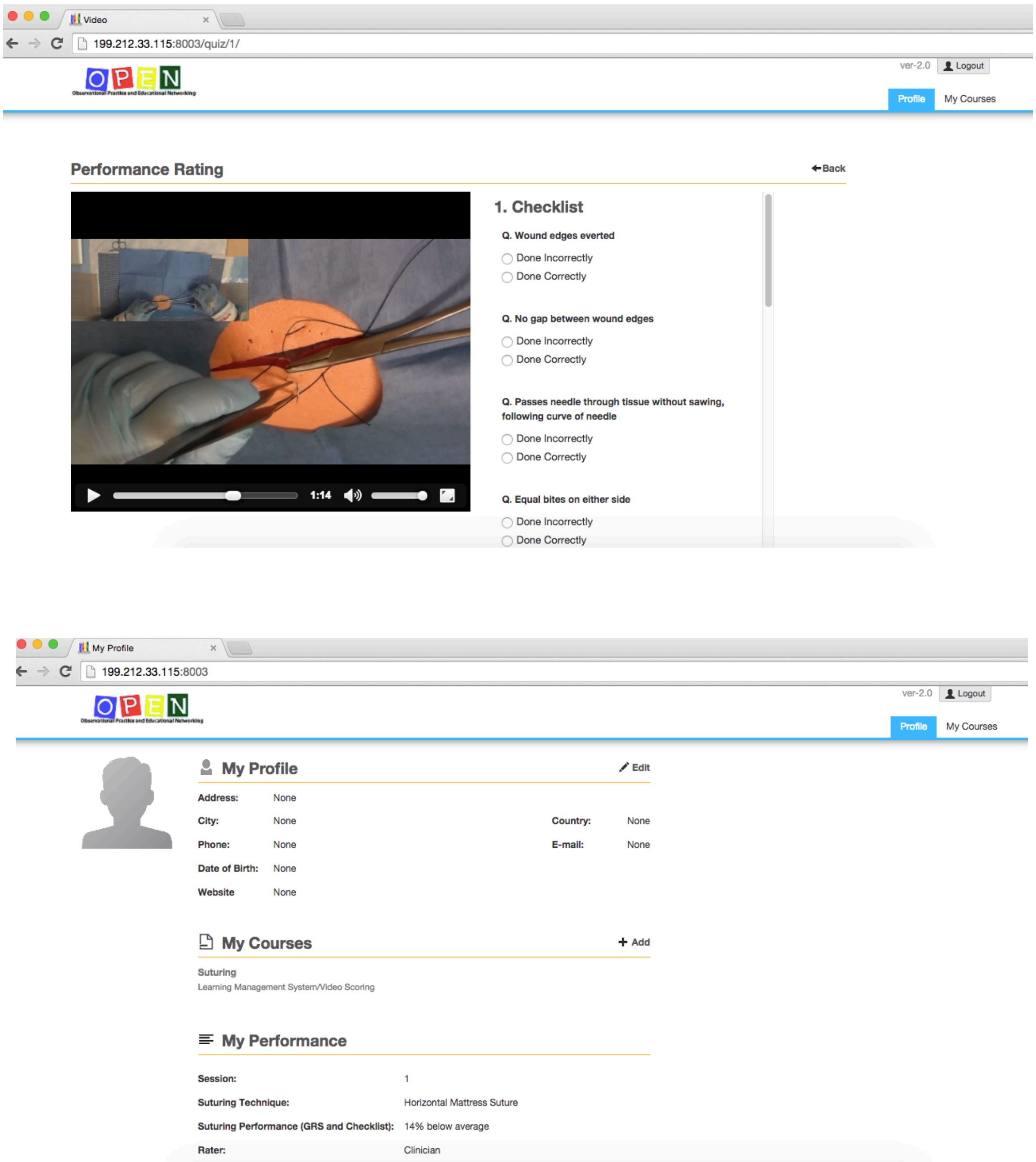

Figure 4.2. A screenshot of customized features within OPEN that all trainees used. **A.** An example of the horizontal mattress suture performance video that trainees scored on the GRS and CL within OPEN; **B.** An example of the performance summary provided to the nCL trainees, which indicates that the trainee performed the *Session 1* horizontal mattress suture below the average.

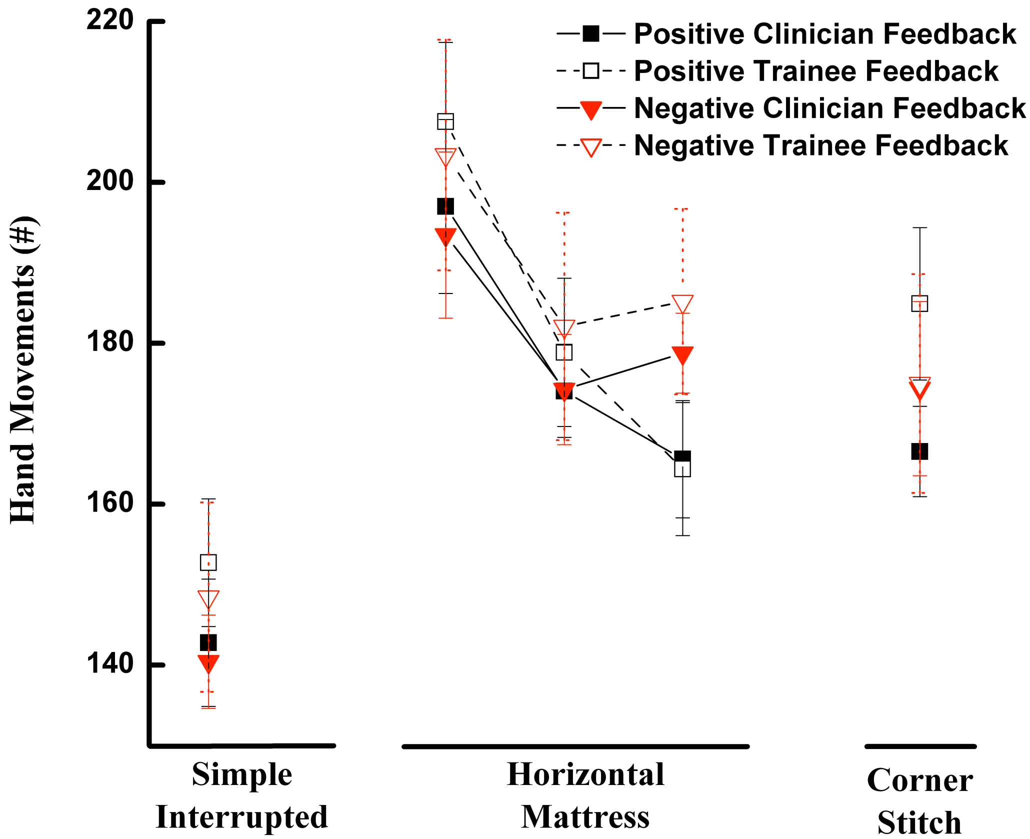

Figure 4.3. Number of Hand Movements (ICSAD measure) for pCL, pTR, nCL, nTR groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (24 hours later). Error bars represent standard error of the mean.

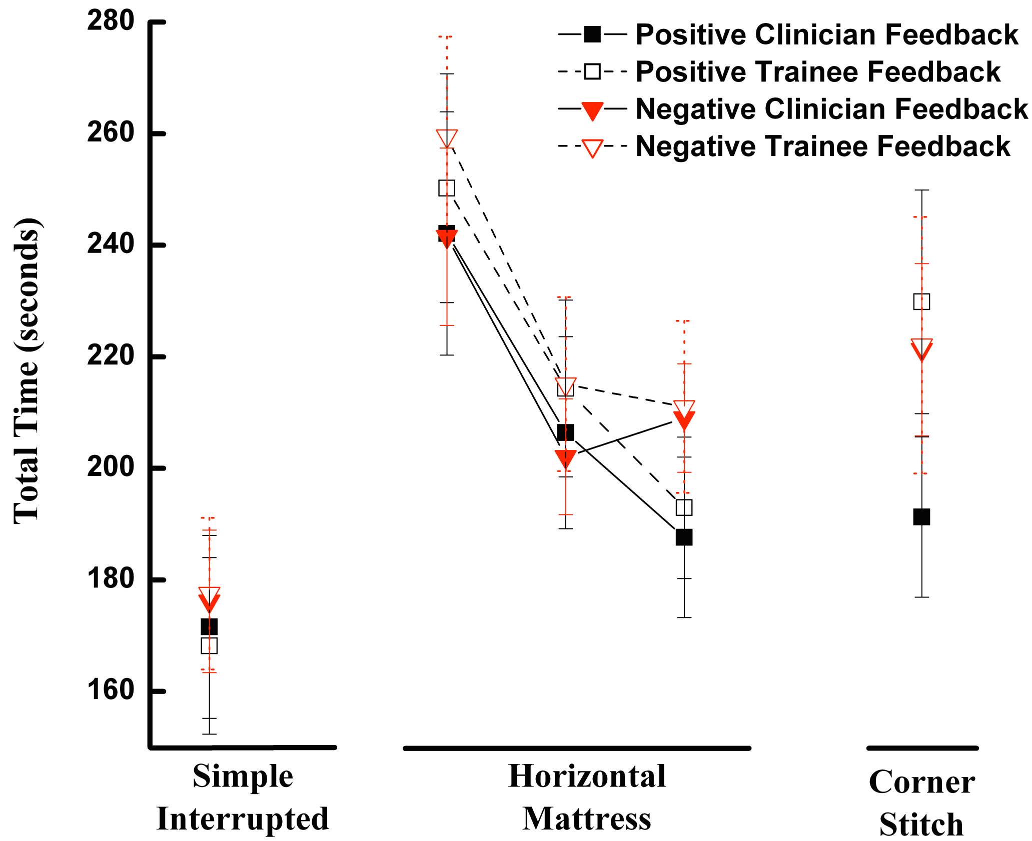

Figure 4.4. Total (suture) Time (ICSAD measure) for pCL, pTR, nCL, nTR groups during the simple interrupted suture, horizontal mattress suture, and corner stitch suture. The simple interrupted suture and horizontal mattress suture means each consist of two trials. The corner stitch represents one trial. Also, the simple interrupted suture and the first two horizontal mattresses were completed during *Session 1*; the last horizontal mattress and the corner stitch were completed during *Session 2* (24 hours later). Error bars represent standard error of the mean.

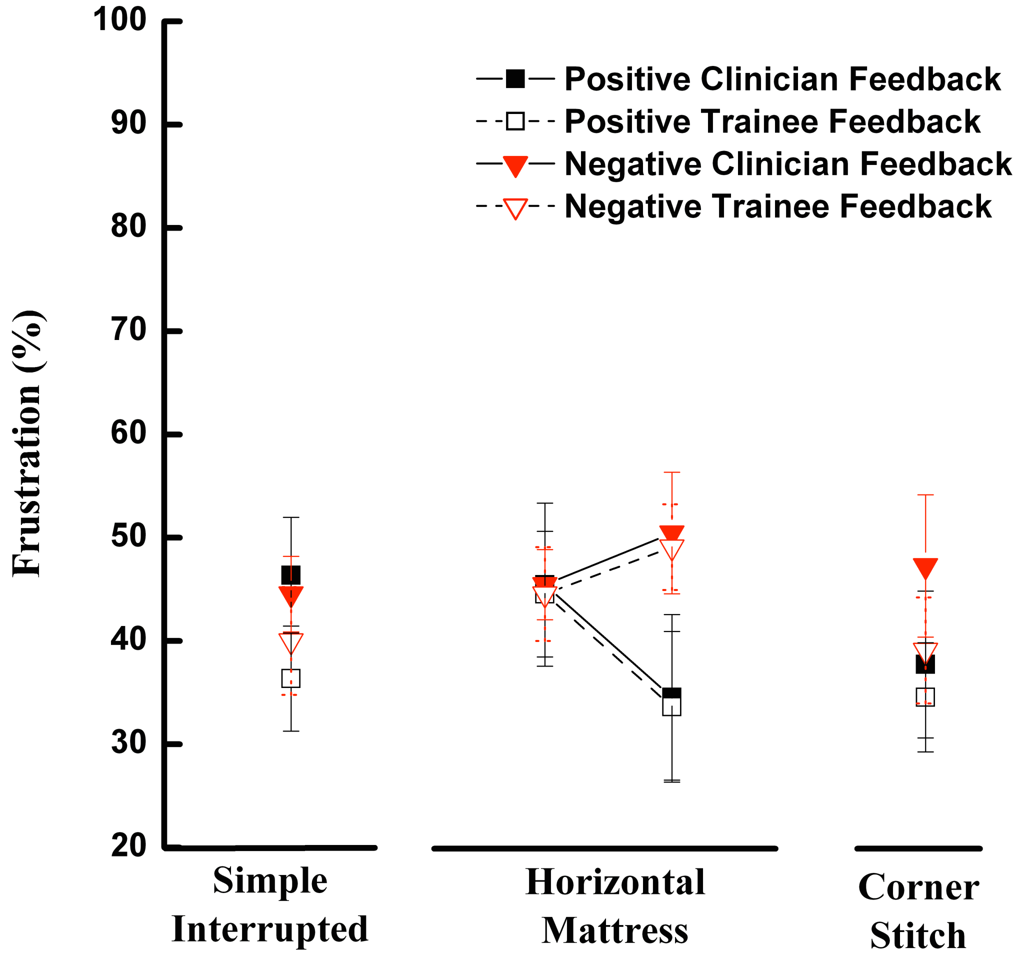

Figure 4.5. Suturing frustration ratings for the pCL, pTR, nCL, nTR groups following the performance of the simple interrupted suture and the horizontal mattress suture during *Session 1* and following the performance of the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (24 hours later). Error bars represent standard error of the mean.

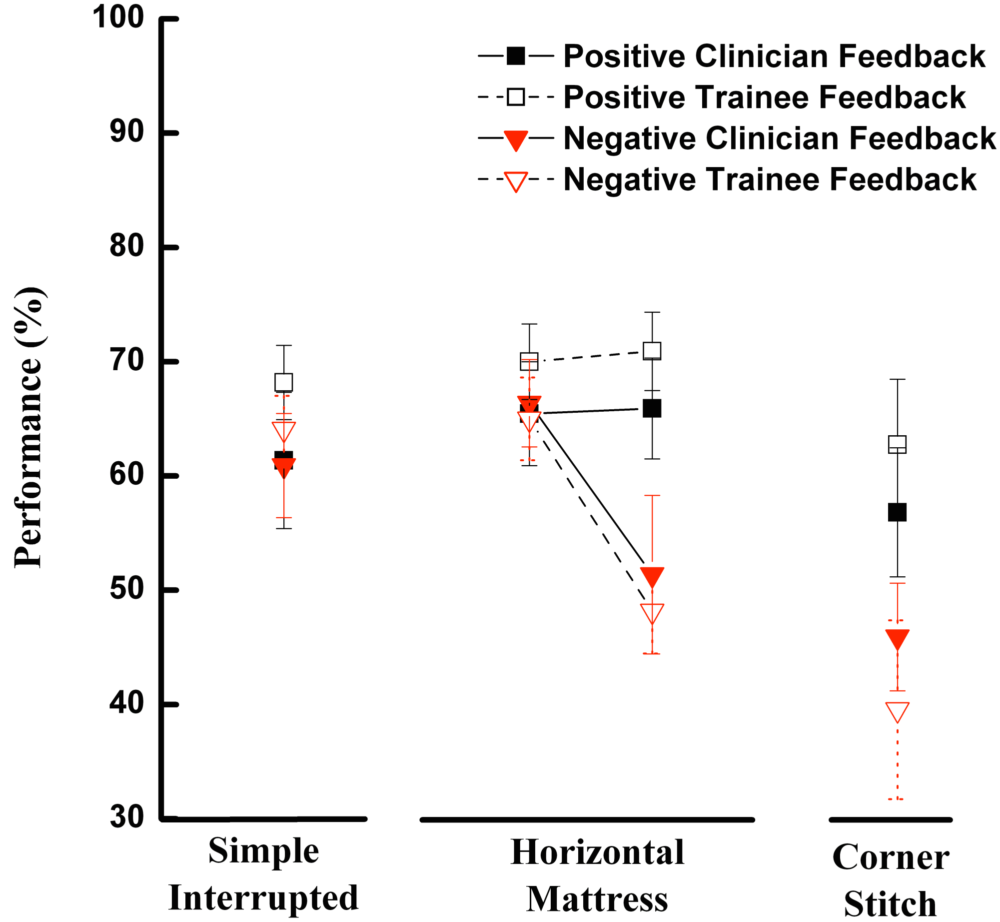

Figure 4.6. Suturing performance ratings for the pCL, pTR, nCL, nTR groups following the performance of the simple interrupted suture and the horizontal mattress suture during *Session 1* and following the performance of the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (24 hours later). Error bars represent standard error of the mean.

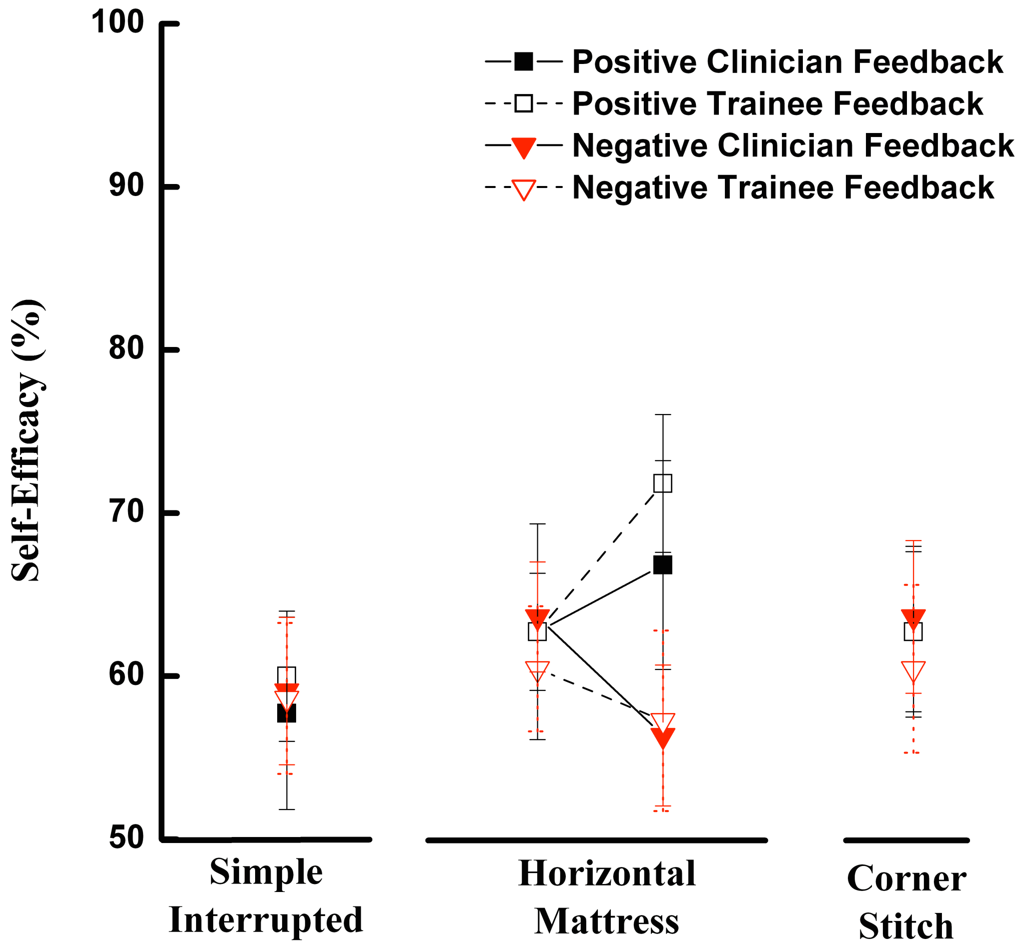

Figure 4.7. Suturing self-efficacy ratings for the pCL, pTR, nCL, nTR groups prior to performing the simple interrupted suture and the horizontal mattress suture during *Session 1* and prior to performing the horizontal mattress suture (delayed retention) and corner stitch (transfer test) during *Session 2* (24 hours later). Error bars represent standard error of the mean.

Table 4.1: Participant demographics and psychological ratings

	Positive Clinician Social-Comparative Feedback (pCL) n=11 *M* (*SD*)		Positive Trainee Social-Comparative Feedback (pTR) n=11 *M* (*SD*)		Negative Clinician Social-Comparative Feedback (nCL) n=11 *M* (*SD*)		Negative Trainee Social-Comparative Feedback (nTR) n=11 *M* (*SD*)	
Age	22.7	(1.2)	23.0	(2.0)	24.3	(3.2)	23.2	(2.5)
Situational Motivation (7-pt scale)								
Intrinsic Motivation	5.3	(0.9)	5.3	(1.1)	5.0	(0.8)	4.7	(1.0)
Identified Regulation	5.7	(0.5)	5.9	(0.7)	6.0	(0.7)	5.4	(1.1)
External Regulation	2.6	(1.4)	2.3	(0.9)	1.8	(0.9)	2.2	(1.2)
Amotivation	1.7	(0.5)	1.8	(0.7)	1.6	(0.6)	1.7	(0.6)
Global Self-esteem (5-pt scale)	3.6	(0.5)	3.8	(0.4)	3.8	(0.4)	3.9	(0.7)
Suturing: Importance (/100%)	80.9	(12.2)	86.4	(17.5)	82.7	(12.7)	75.5	(18.1)
Suturing: Self-efficacy (/100%)								
SI	57.7	(19.5)	60.0	(13.2)	59.1	(15.0)	58.6	(15.3)
HM Acquisition	62.7	(22.0)	62.7	(11.9)	63.6	(11.2)	60.5	(12.7)
HM Retention	66.8	(21.2)	71.8	(14.0)	56.4	(14.3)	57.3	(18.4)
CS	62.7	(17.4)	63.6	(16.3)	61.4	(15.5)	53.2	(17.1)
SI: NASA (/100%)								
Mental Demand	71.8	(11.5)	70.9	(11.4)	68.2	(10.8)	70.9	(15.1)
Effort	70.9	(12.8)	65.5	(11.3)	71.8	(12.5)	72.7	(10.1)
Performance	61.4	(19.8)	68.2	(10.8)	60.9	(15.1)	64.1	(9.7)
Frustration	46.4	(18.6)	36.4	(16.9)	44.5	(12.1)	40.0	(17.3)
HM Acquisition: NASA (/100%)								
Mental Demand	69.5	(17.4)	73.6	(13.6)	74.5	(13.7)	70.5	(14.6)
Effort	68.2	(19.4)	72.7	(14.9)	70.5	(10.1)	70.5	(10.6)
Performance	65.5	(15.1)	70.0	(11.0)	66.4	(12.7)	65.0	(12.0)
Frustration	45.5	(26.2)	44.5	(20.2)	45.5	(11.3)	44.5	(15.1)
HM Retention: NASA (/100%)								
Mental Demand	57.3	(23.2)	63.6	(16.9)	65.5	(15.1)	62.7	(14.9)
Effort	57.3	(21.1)	65.5	(19.2)	65.9	(13.9)	65.9	(12.4)
Performance	65.9	(14.6)	70.9	(11.4)	51.4	(23.0)	48.2	(12.3)
Frustration	34.5	(26.6)	33.6	(24.2)	50.5	(19.6)	49.1	(13.8)
CS: NASA (/100%)								
Mental Demand	67.7	(22.5)	69.1	(23.9)	72.7	(11.9)	64.5	(19.2)
Effort	66.8	(18.7)	64.5	(19.2)	70.5	(15.6)	69.5	(14.9)
Performance	56.8	(18.7)	62.7	(19.0)	45.9	(15.6)	39.5	(25.9)
Frustration	37.7	(23.6)	34.5	(17.5)	47.3	(22.8)	39.1	(17.0)

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

Table 4.2: Participant behavioural outcomes on suturing

	Positive Clinician Social-Comparative Feedback (pCL) n=11 *M* (*SD*)		Positive Trainee Social-Comparative Feedback (pTR) n=11 *M* (*SD*)		Negative Clinician Social-Comparative Feedback (nCL) n=11 *M* (*SD*)		Negative Trainee Social-Comparative Feedback (nTR) n=11 *M* (*SD*)	
Suturing trials: Total Time								
SI trial 1	188.0	(65.7)	190.2	(72.4)	196.4	(48.0)	188.5	(46.6)
SI trial 2	155.1	(44.3)	146.2	(36.5)	155.9	(43.3)	166.6	(49.4)
HM1 trial 1	261.3	(89.8)	271.6	(76.2)	251.2	(47.9)	280.2	(62.4)
HM2 trial 1	221.1	(58.6)	230.0	(57.6)	213.3	(46.9)	228.8	(59.4)
HM3 trial 1	222.9	(58.5)	228.8	(62.2)	231.9	(64.1)	238.9	(57.3)
HM1 trial 2	191.6	(57.3)	198.7	(50.1)	190.9	(24.8)	201.4	(47.7)
HM2 trial 2	199.2	(49.7)	203.7	(40.8)	229.3	(35.3)	231.5	(58.8)
HM3 trial 2	176.1	(49.3)	182.2	(45.8)	188.7	(46.3)	190.5	(45.3)
CS trial 1	191.3	(47.7)	229.9	(66.5)	221.3	(51.2)	222.1	(76.3)
Suturing trials: Hand Movements								
SI trial 1	149.8	(34.1)	164.2	(36.3)	154.5	(26.7)	148.5	(37.9)
SI trial 2	135.7	(20.1)	141.3	(30.2)	126.3	(18.1)	148.5	(46.0)
HM1 trial 1	214.3	(49.3)	224.1	(41.3)	199.4	(35.8)	215.6	(50.2)
HM2 trial 1	178.4	(25.0)	186.4	(29.2)	179.2	(34.9)	189.8	(49.8)
HM3 trial 1	179.7	(31.1)	191.0	(28.7)	187.5	(42.8)	191.2	(48.8)
HM1 trial 2	169.7	(16.6)	171.4	(35.0)	169.3	(23.7)	174.4	(48.1)
HM2 trial 2	173.0	(29.1)	176.5	(26.5)	188.2	(26.4)	204.9	(44.9)
HM3 trial 2	158.2	(22.3)	152.3	(31.4)	169.4	(20.4)	165.5	(32.8)
CS trial 1	166.5	(18.6)	184.9	(31.4)	174.4	(35.9)	175.0	(45.1)
Practice sutures: Total Number								
SI (in 15m)	4.3	(0.6)	4.2	(0.6)	3.9	(0.5)	4.3	(0.6)
HM (in 10m)	1.5	(0.5)	1.4	(0.5)	1.5	(0.5)	1.3	(0.5)
Number of participants who watched video during practice								
SI	8/11	-	6/11	-	8/11	-	7/11	-
HM	7/11	-	8/11	-	6/11	-	7/11	-
Number of participants that adopted specific strategies related to performing suturing techniques								
Strategies before task	9/11	-	8/11	-	4/11	-	5/11	-
Strategies during task	0/11	-	1/11	-	4/11	-	3/11	-
Strategies before and during task	2/11	-	2/11	-	3/11	-	3/11	-

Note. M = mean; SD = standard deviation; SI = simple interrupted suture; HM = horizontal mattress suture; HM1 = first set of horizontal mattress sutures completed during *Session 1*; HM2 = second set of horizontal mattress sutures completed during *Session 1*;
HM3 = third set of horizontal mattress sutures completed during *Session 2*; CS = corner stitch suture; NASA = National Aeronautics and Space Administration-Task Load Index

CHAPTER 5:

GENERAL DISCUSSION

5.1 – THESIS SUMMARY

This dissertation includes three independent studies designed to examine the influence of social-comparative feedback during motor skill acquisition in a subset of highly-motivated learners (i.e., medical trainees). The research questions and findings of this dissertation are novel and provide important theoretical and practical contributions to the existing literature. Previous research (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012; Wulf & Lewthwaite, 2016) suggests that socially-relevant feedback (i.e., social-comparative feedback) modifies the learning process. Specifically, the learning process is facilitated when learners adopt a better-than-average mindset, while a below-average mindset does not hinder learning compared to a control condition (i.e., no social-comparative feedback) (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2014; Wulf et al., 2010, 2012; Wulf & Lewthwaite, 2016). It has been proposed that the learning benefits of a better-than-average mindset are due to the motivational properties that feedback provides (Wulf & Lewthwaite, 2016). However, from a theoretical perspective, the motivation at the level of the learner has been largely neglected in studies that propose motivational explanations for the better-than-average feedback effect (Eliasz, 2012; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2016). Therefore, it is unclear how motivation at the level of the individual contributes to these theoretical propositions. From a practical perspective, highly-motivated learners like medical trainees often receive social-comparative feedback during their training; however, how this feedback is internalized and used by the medical trainee is not at all understood in the culture of medicine (Lefroy et al., 2015). This dissertation was therefore designed to address these theoretical and applied gaps by using a framework of perspectives from psychology, sociology, motor learning and medical education.

For all three studies described in this dissertation, novice pre-clerkship medical trainees were provided with manipulated feedback information (i.e., social-comparative feedback) while they were learning motor skills to suggest that they were performing better or worse than the average – regardless of their actual performance. The control condition in Study 1 and 2 did not receive any social-comparative feedback. Findings from Study 1 (Chapter 2) provide the first demonstration that highly-motivated learners like medical trainees do not interpret social-comparative feedback in the same manner as other learners (non-medical) studied in the literature. Specifically, adopting a better-than-average mindset did not facilitate learning and in some cases even hindered it (Study 1), whereas a below-average mindset was consistently detrimental to psychological and behavioural outcomes in medical trainees. This effect was regardless of the motor task that medical trainees were learning (i.e., computer key-pressing or suturing). Study 2 (Chapter 3) replicated these findings and extended them to a medically-relevant context by modifying the feedback delivery features during the acquisition of basic surgical techniques. Study 3 (Chapter 4) further extended these results and provided evidence that this effect still persisted regardless of who the feedback provider was (i.e., hypothetical 'expert' or 'peer' delivering this feedback). Collectively, the findings of this dissertation suggest that internalizing above-average feedback does not translate to additional learning benefits whereas the *experience* of receiving negative social-comparative feedback is damaging on both a psychological and behavioural level for novice medical trainees learning procedural skills.

5.2 – THEORETICAL CONTRIBUTIONS AND CONSIDERATIONS

The findings of this dissertation have important theoretical implications, with respect to the literatures on both motivation and feedback. The theoretical contributions and considerations are outlined below (Subsections 5.2.1, 5.2.2, and 5.2.3).

5.2.1 – *Same Information, Different Interpretation*

Positive Information

There is a robust line of research suggesting that different levels of the learning process will be facilitated when the learner receives information or instruction that is positive in nature (Aronson et al., 2002; Avila et al., 2012; Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Dweck, 1999, 2002, 2006; Eliasz, 2012; Hutchinson et al., 2008; Janelle et al., 1997; Janelle et al., 1995; Lee et al., 2016; Lewthwaite et al., 2015; Lewthwaite & Wulf, 2010;

Patterson & Carter, 2010; Saemi et al., 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2009, 2016; Wulf et al., 2010, 2012). However, as the findings of this dissertation would suggest, once the motivation level of the learner is considered, positive information no longer provides added learning benefits. There are three potential explanations, all related to the *meaningfulness* of the feedback that was delivered, for why highly-motivated medical trainees did not experience the enhanced benefits that positive information typically offers (in this case, positive social-comparative feedback).

One explanation for why positive social-comparative feedback did not provide additional learning benefits could be due to the nature of the feedback itself. For example, the instructions and feedback used in this dissertation emphasized performance goals rather than learning goals, which have been previously found to hinder learning (e.g., drawing attention to the self rather than the task) (Hattie & Timperley, 2007). Learning goals are more effective for skill acquisition because they increase intrinsic motivation and performance compared to goals that draw attention to outcome and ability (Ames, 1992; Dweck & Elliott, 1983), or the ego (Nicholls, 1984). Since the medical trainees already reported higher levels of intrinsic motivation, learning goals may have been perceived to be more meaningful during the learning process compared to the performance feedback they received instead.

Another explanation for why positive social-comparative feedback did not enhance psychological and behavioural measures in the medical trainees could have been because it was not potent enough to alter self-efficacy ratings beyond a no-feedback condition. For instance, in some motor learning studies where positive feedback improved behaviour, learners also reported increases to motivation and self-efficacy (Badami et al., 2011; Saemi et al., 2012). Since self-efficacy is a robust predictor of behaviour (Bandura, 1997; Moritz et al., 2000; Schunk, 1990, 1995), the lack of additional learning benefits compared to a control condition could have been due to the lack of group differences found for self-efficacy ratings.

A final explanation for why positive social-comparative feedback did not elicit additional learning benefits compared a control condition could have been due to the learner him/herself. It is very possible that the medical trainees may not have perceived the positive social-comparative feedback delivered in this program of research to be meaningful because they already had high levels of motivation and self-esteem to begin with. This is evident from the behaviour of the control group in both Study 1 and 2; where behaviour and psychological ratings like self-efficacy still increased despite the absence of feedback. Moreover, medical trainees do report that they enjoy receiving positive feedback; anecdotally in this dissertation as well as in other clinical research studies. Additionally, there is also evidence that they are driven to seek feedback more often when it is positive in nature (Harrison et al., 2013) however, Archer (2010) suggests that motivation is not a problem in medical trainees and therefore the focus of feedback should not have to be to motivate.

When A Non-Response Becomes A Negative Response

Although receiving positive social-comparative feedback did not provide any added learning benefits for the medical trainees in this dissertation, the reinforcing provision of this feedback for a less training-relevant task (i.e., computer key-pressing task) started to actually become damaging to their learning process (e.g., they produced more errors in the delayed key-pressing retention test). Interestingly, in Study 1 not only did positive social-comparative feedback become detrimental for learning the less-relevant key-pressing task, trainees receiving this feedback began to also adopt less effective strategies for the training-relevant task that followed (i.e., only 20% of the PF trainees re-watched the suturing videos while practicing the suturing techniques). This behaviour suggests that the positive affective state being experienced by PF trainees during the key-pressing task was beginning to inflate their perceived success for the suturing task that followed (e.g., overconfidence) (Baumeister, 1989). In summary, positive thoughts, affect, and optimism typically lead to favourable outcomes (Aronson et al., 2002; Avila et al., 2012; Chiviacowsky & Wulf, 2002; Eliasz, 2012; Fredrickson, 2001; Fredrickson & Branigan, 2005; Gasper & Clore, 2002; Geers et al., 2007; Isen, 1987, 1990; Lewthwaite & Wulf, 2010; McKay et al., 2012; Pekrun et al., 2002; Scheier & Carver, 1985; Stoate et al., 2012; Taylor & Brown, 1988; Wulf et al., 2010, 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2016); however, for highly-motivated learners such as medical students, reinforcing above-average feedback for a less important task can hinder performance of that specific task but also have psychological carry-over effects for future tasks.

Negative Information

Motor learning studies that have explored the influence of social-comparative feedback demonstrate that learners are typically not sensitive, at least on a behavioural level, to receiving negative social-comparative feedback (i.e., this feedback is not detrimental to learning) (Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf & Lewthwaite, 2016). The results of this dissertation however, suggest that novice medical trainees have difficulty coping with below-average feedback. It is therefore important to determine which individuals are sensitive to negative information and why, especially if that negative information has implications on longer-term effects (i.e., motor learning). Two potential explanations, both related to *coping* with the feedback that was delivered, for why highly-motivated medical trainees experienced psychological and behavioural detriments when receiving negative social-comparative feedback are considered next.

One explanation for these psychological and behavioural detriments could be related to the lack of experience that the novice medical trainees had in coping with negative information. For instance, medical admissions implement selection procedures aimed to choose the most highly-motivated and achieving future trainees (Hulsman et al., 2007; Steele, 2011; Turner & Nicholson, 2011). As a result, prior to entering medical school, there is a high possibility that these learners had a history of mastery experience (at least on an academic level) to suggest that they were above average. In turn, these learners may not have been exposed to a diverse set of experiences that would have encouraged them to use a variety of coping mechanisms in order to process unfavourable information.

Another explanation for why this information was perceived by the medical trainees in a negative manner could have been due to the intensity of the misalignment between the delivered feedback and their self-perceptions (Aronson, 1992; Festinger, 1957; Frey, 1986; Harmon-Jones, 2012; Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2008; Harmon-Jones & Mills, 1999; Harmon-Jones et al., 2011; Sedikides & Strube, 1997; Steele, 1988). The findings in this dissertation suggest that there was likely a misalignment between the fabricated negative social-comparative feedback that was received and the high motivational levels of the medical trainees, which as a result could have provoked an adverse emotional and behavioural reaction. For instance, due to the high level of motivation (on both a trait and state level), the experience of receiving negative social-comparative feedback could have been perceived to be more threatening to the self (Campbell & Sedikides, 1999). There is also evidence to suggest that the magnitude of resolving this misalignment is associated with motivation, with higher levels facilitating greater urgency to reduce these incongruences (Frey, 1986; Harmon-Jones, 2012, Harmon-Jones & Harmon-Jones, 2002; Harmon-Jones et al., 2011). This could explain why self-efficacy and performance ratings both decreased and frustration levels increased, and why attentional shifts, based on the reported learning strategies, may have differed compared to the other groups. As a result, this potential attempt to remove the dissonance (by altering self-reported ratings and strategies) could have triggered the negative behavioural responses (e.g., self-efficacy being a predictor of behaviour).

5.2.2 – *Shifting Strategies And Attention*

The majority of trainees that received negative social-comparative feedback reported differences related to the suturing technique strategies that they adopted, which provided an indication that they were experiencing differences in attentional focus compared to the other experimental groups. There is a body of motor learning research demonstrating that the wording of task instructions can shift a learner's focus of attention during skill acquisition (McNevin, Shea, & Wulf, 2003; Wulf, Höß, & Prinz, 1998; Wulf & Prinz, 2001; Wulf, Shea, & Park, 2001; Wulf, Weigelt, Poulter, & McNevin, 2003). The focus of attention research has consistently shown that the learning process is facilitated when these instructions trigger a learner to adopt an external focus of attention (where attention is diverted towards the intended movement effect) compared to an internal focus of attention (attention is towards the self) (Wulf, 2013; Wulf & Prinz, 2001). Extending this line of research, this dissertation suggests that feedback (i.e., social-comparative feedback) can also shift a learner's focus of attention during skill acquisition. However, in this dissertation the timing (and not the 'internal/external distance') of the attentional focus differed as a result of the social-comparative feedback that was delivered. Specifically, the majority of the medical trainees receiving negative social-comparative feedback reported adopting strategies while they were performing the suturing techniques, whereas the positive social-comparative feedback and control groups typically reported using strategies *prior to* their suturing performances. The findings also suggest that the negative social-comparative feedback activated a state of negative emotions (e.g., frustration levels increased), which have been related to rehearsal strategies (Pekrun et al., 2002). For instance, some NF trainees reported to be fixated on specific details of the suturing techniques, and even amplifying them, during performance (e.g., knot-tying, entering the skin). The reported fixations as a result of the negative social-comparative feedback in this dissertation are also consistent with early work in emotions research that indicates negative affect narrows attentional focus (Easterbrook, 1959). Collectively, the three studies in this dissertation suggest that novice medical trainees are more sensitive to negative information, particularly negative social-comparative feedback; however, this sensitivity could be due various factors or even a combination of factors as a result of the feedback that was received (e.g., previous experience, dissonance, attentional or mindset shifts).

5.2.3 – *The Need To Reconsider Motivation And Social-Comparative Feedback*

Both motivation and social-comparative feedback have been overlooked in various lines of research. The critical aspect is that both are potent enough to modify behaviour and have long-terms effects. Considering the complexities of both of these potent variables, research protocols need to be designed to understand these factors from different lenses in addition to the specifics that each lens may also offer. Therefore, these studies need to be carefully constructed and reported with great detail.

Motivation

There are over 30 well-developed theories of motivation but in general they largely overlook the important role of individual differences. Our research demonstrates that motivation at the level of the individual is important to consider in order to better understand the interplay between feedback and motivation during the learning process. Motor learning studies proposing that feedback offers learning benefits due to its motivational properties have also neglected to consider motivation at the level of the learner (Wulf & Lewthwaite, 2016). Instead, these studies have explored feedback effects by segregating learners based on age (i.e., children, young adults, older adults) (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010, Experiment 2 in 2012) and ignoring the *type* of learner that is engaged in the learning process. The findings of this dissertation reveal that negative social-comparative feedback is harmful for highly-motivated learners like medical trainees.

There is also a possibility that negative social-comparative feedback is detrimental in other types of contexts or to other types of learners; however, the majority of motor learning studies that have explored the motivational role of feedback have eliminated the inclusion of the below-average group (Lewthwaite, & Wulf, 2012; Stoate et al., 2012; Wulf & Lewthwaite, 2016). Even as researchers, we are wired to avoid negatives wherever possible. Without a doubt, delivering negative social-comparative feedback (and negative feedback in general) is uncomfortable and difficult. However, although it is important to know that above-average feedback can facilitate learning, it is also important to better understand in which contexts feedback is detrimental to the learning process. Harmful learning effects have major consequences, especially in fields like medicine where those consequences can be dangerous. By not including negative social-comparative feedback conditions, we run the risk of looking at feedback through rose-coloured glasses. It is therefore important to understand, in an ethical manner, which conditions and which types of feedback are harmful so that practical interventions can be designed to mitigate the detrimental effects of negative social-comparative feedback rather than avoid them (e.g., by not delivering negative social-comparative feedback in experiments).

Social-Comparative Feedback

The potency of social-comparative feedback has also been largely overlooked in different lines of research. Our results demonstrate that social-comparative feedback, even presented to learners once and in a vague manner, is powerful enough to modify psychological and behavioural outcomes during the learning process. Therefore, in addition to learner motivation, it is also important to isolate and understand how different *types* of feedback influence the learner throughout the skill acquisition process. Moreover, motor learning studies have used various techniques when exploring the motivational properties of feedback.

Specifically, the role of social-comparative feedback has been shown several times to influence the learning process (Avila et al., 2012; Eliasz, 2012; Lewthwaite & Wulf, 2010; Wulf et al., 2010, 2012 (Experiment 1); Wulf & Lewthwaite, 2016). However, despite the significant influence of social-comparative feedback on learning compared to other techniques (i.e., conceptions of ability) (Wulf et al., 2013), its independent effects have been largely ignored in other motor learning studies related to feedback (McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2013; Wulf & Lewthwaite, 2016). In these studies, the researchers explored a range of combined techniques that manipulated a learner's outcome expectations prior to skill acquisition, which they termed 'enhanced expectancies'; however, all of these mentioned studies included the delivery of social-comparative feedback. Therefore, considering social-comparative feedback's independent effectiveness (Wulf et al., 2013), it is possible that this type of feedback may have been driving the beneficial effect of the 'enhanced expectancies' in these particular studies (McKay et al., 2012; Stoate et al., 2012; Wulf et al., 2013; Wulf & Lewthwaite, 2016). Other lines of research suggest that individuals generally use social-comparative feedback to help them understand their own performance (Triplett, 1898), even if they are not consciously aware of this (Wood, Taylor, Lichtman, 1985). Interestingly, Wood and colleagues (1985) found that participants often reported that they did not compare themselves with others but then spontaneously reported numerous comparisons throughout the research interviews that were conducted (Wood et al., 1985). Therefore, these findings collectively shed light on the importance of social-comparative feedback being considered independently in research protocols. Feedback is just like any other experimental manipulation, which has to be acknowledged and controlled in research protocols. In clinical education research, the details of the feedback interactions between the educators or experimenters and trainees are rarely provided (e.g., 'feedback was delivered to the trainees'). It is therefore important that researchers disclose the manner in which the social-comparative feedback (or any other feedback) was delivered (e.g., the type, the frequency).

5.3 – APPLIED CONTRIBUTIONS AND CONSIDERATIONS

The findings of this dissertation also provide important practical implications, particularly contributing to the field of medical education. Often social-comparative feedback is provided to medical trainees throughout their training; however, how this type of feedback is translated and coped with by medical trainees is not well understood in clinical education (Lefroy et al., 2015). Furthermore, in a culture where the foundation is motivation, understanding how motivated learners like medical trainees react to the feedback that they usually receive during their training is critical. Neglecting motivation from the feedback conversation removes a large part of the conversation in this context, including how it may impact future feedback-seeking behaviours. The applied contributions and considerations are outlined below (Subsections 5.3.1, 5.3.2, and 5.3.3).

5.3.1 – *Feedback Through A Cultural Lens: The Culture Of Medicine*

In Chapter 1, feedback was reviewed from the perspective of an informational, motivational and social lens. In the motor learning domain, the dominant perspective on feedback has been through an informational lens (Salmoni et al., 1984). Recently, approaches to understanding feedback during motor skill acquisition have begun to include a motivational and social perspective (Avila et al., 2012; Badami et al., 2011; Chiviacowsky & Wulf, 2002, 2007; Chiviacowsky et al., 2012; Chiviacowsky et al., 2008; Chiviacowsky et al., 2009; Eliasz, 2012; Janelle et al., 1997; Janelle et al., 1995; Lewthwaite & Wulf, 2010; Patterson & Carter, 2010; Saemi et al., 2012; Wulf et al., 2014; Wulf & Lewthwaite, 2016; Wulf et al., 2010, 2012). What is missing from this multidimensional perspective of feedback is a cultural lens. Adopting a cultural lens to better understand feedback is both relevant to the findings of this dissertation but also to medical education (Lefroy et al., 2015; Watling, 2014a, 2014b). For instance, these data may only be relevant to medical trainees and not other highly-motivated learners (who typically overcome challenges due to their high confidence and resilience); therefore, it is important to understand the influences of feedback (and different types of feedback) in a culture where motivation is the fundamental core (i.e., the culture of medicine). The medical culture recognizes and values feedback in theory; however, the realities of the clinical world result in feedback conversations being neglected (Ende, 1983; Molloy, 2009; Watling, 2014a, 2014b). Understanding feedback from this perspective will help medical education transform the feedback conversation and work towards developing a feedback culture as Watling has argued for (2014a, 2014b). The combined findings of this dissertation as well as other relevant lines of research (e.g., feedback research that is studied using different approaches) also suggest that feedback, especially in an applied field like medical education, needs to be understood not from a unitary perspective but rather from a multidimensional perspective that embraces the custom of using a variety of lenses. In order to appreciate the intricacies of feedback interactions that an applied setting offers, clinical education needs to both embrace and appreciate the feedback chaos.

5.3.2 – *Implications For Remediation*

The most important and potentially impactful discovery resulting from this dissertation is that novice medical trainees have difficulty in receiving information that they are performing worse than their peers – regardless of the task and feedback provider. Receiving and translating this unfavourable information has detrimental consequences for both their psychological and behavioural outcomes. As a result, research needs to understand why this may be the case and how to alleviate these detrimental learning effects. After all, this is the group of students that the clinical instructors want to help the most. This main finding is particularly important in the realm of remediation, where underperforming trainees are described as struggling with their training trajectories, identifying their struggles, and with receiving as well as making use of challenging feedback (Chou, Kalet, & Hauer, 2014). For numerous reasons (e.g., scarce faculty resources, lack of identifying the underlying learner issues), remediation interventions often lack the built-in support and guidance that these struggling trainees require in order to successfully move forward (Cleland et al., 2013). In their systematic review of remediation interventions, Cleland and colleagues (2013) identified that most remediation inventions are not proactive in their approach (i.e., targeting novice trainees) but rather the interventions reactively target underperforming students in their later years of training. A lack of proactive approaches reduces the chances of success that these remediation inventions will have due to the ineffective feedback coping strategies that medical trainees seem to adopt (i.e., avoiding to seek and receive disapproving feedback). For instance, Harrison and colleagues (2013) identified that low performers on the OSCE examination were rarely driven to view additional information about their poor performance, although these were the trainees that would benefit the most from the detailed personalized feedback summaries that were available to them. This is also in line with research outside of clinical education (Pyszczynski, Greenberg, & LaPrelle, 1985), which has demonstrated that learners who were failing showed a lack of interest in acquiring additional information when they expected it to reveal that most of the other learners performed well, whereas they became driven to seek additional feedback when they expected it to reveal that most other learners performed poorly. The findings of both this dissertation as well as those from the literature in remediation (Chou et al., 2014; Cleland et al., 2013), suggest an urgency in the development of proactive approaches to help trainees (not just struggling trainees) learn how to handle adverse information before it becomes a vicious cycle of negative events where remediation is the only option left. Due to the negative experiences trainees seem to have with receiving challenging information, the initial solution may be to avoid or cease the delivery of negative feedback; however, clinical educators need to be aware that attending to the emotions of trainees can create even greater barriers to the feedback culture (Ende, 1983). In all, there has to be a shift in medical education from the current remediation approach of *reacting* to underperforming trainees to instead investing in the development of methods that will provide *proactive* support for trainees to receive unfavourable information during their training so that they will be better prepared for the realities of independent practice. The next subsection (5.3.3) outlines some recommendations based on the combined findings of this dissertation and other relevant lines of research.

5.3.3 – *Recommendations*

Is Social-Comparative Feedback Harmful For Medical Training?

Medical trainees are often provided with social-comparative feedback during their training. However, the findings of this dissertation suggest that providing novice medical trainees with social-comparative feedback during skill acquisition is detrimental to them on both a psychological and behavioural level. As a result, this feedback may be unintentionally harming novice trainees. Abandoning social-comparative feedback in medical training however, is not realistic nor is it an appropriate solution. Social comparisons are present in daily situations, either consciously or unconsciously. Additionally, it is currently unknown if social-comparative feedback even influences senior medical trainees. However, for novice medical trainees social-comparative feedback may emphasize the 'undergraduate mentality'. One proposition would be to delay social-comparative feedback until trainees are immersed in the medical culture and have opportunities to receive more diverse performance feedback (compared to the performance feedback they would have typically received in their pre-medical training). Pre-clerkship years are also an ideal time to invest in proactive interventions to help novice trainees cope with challenging feedback using different strategies.

Redirecting The Focus From The Feedback Provider To The Feedback Receiver

The majority of feedback research in clinical education has focused on feedback guidelines for clinicians, faculty development, and more or less, placed the sole responsibility of the feedback conversation on the feedback provider. Although clinical educators are important in translating their experienced observations into meaningful information for the trainee, they should not have to fear engaging in feedback conversations (Ende, 1983; Molloy, 2009). Instead, the findings of this dissertation would suggest that novice medical trainees have difficulty receiving below-average feedback *regardless of who delivers it*. Therefore, the first recommendation is to shift the focus and some of the responsibility from the feedback provider to the feedback receiver (i.e., the medical trainee). The feedback provider could be highly effective at delivering feedback but if the medical trainee does not accept the feedback or cannot translate it into meaningful information then the feedback interaction is still an unsuccessful one. Medical trainees therefore need to receive guidance and training in coping with challenging information, especially in their junior years.

Redirecting The Focus From Self-Assessment To Guided Coping

The extreme opposite of putting the responsibility on the feedback provider is to direct all accountability to the feedback receiver (e.g., self-assessment interventions). This method has been appealing in many areas of research including medical education. However, self-assessment interventions have been generally shown to be flawed and ineffective, including in clinical education (Eva & Regehr, 2005; Davis et al., 2006; Dunning, Heath, & Suls, 2004). There are various lines of research to explain why self-assessment may not be successful. For one, we tend to rate ourselves better than the average on many factors, even including most trait dimensions (Alicke, 1985; Alicke, Klotz, Breitenbecher, Yurak, & Vredenburg, 1995). In addition, our inherent bias to view ourselves in a positive manner (Jussim et al., 1995; Sedikides, 1993; Taylor & Brown, 1988) provides a great challenge, if not impossible, to detach our emotions from such a personalized assessment. If assessment does not match self-perceptions, then learners may experience adverse reactions as they did in this dissertation. Therefore, the second recommendation is to encourage a shift away from self-assessment interventions where the responsibility is solely on the trainee and adopt more guided approaches (e.g., guided self-assessment, guided reflection, guided self-regulation) for both seeking and coping with feedback (Sargeant et al., 2008).

Redirecting The Focus From Reflection-On-Feedback To Shifting Mindsets

Developing interventions to shift learner mindsets may be a better strategy for helping novice medical trainees cope with unfavourable feedback compared to self-reflection and/or feedback reflection since many lines of research have suggested that these are inherently flawed. Shifting the mindset is one strategy that has been very effective in research outside of clinical education (Aronson et al., 2002; Cimpian et al., 2007; Dweck, 1999, 2002, 2006; Dweck, & Leggett, 1988; Good et al., 2003; Jourden et al., 1991; Wulf & Lewthwaite, 2009). Interestingly, when learners adopt a mindset such as the growth mindset (compared to a fixed one) (Section 1.7 in Chapter 1), they do not ignore and overlook errors but rather their attention is allocated to the errors and they are able to correct them more effectively (Moser, Schroder, Heeter, Moran, & Lee, 2011). Helping medical trainees shift their mindsets prior to receiving feedback may help facilitate coping mechanisms for when challenging information is received.

Redirecting The Focus From Error-Free Training To Autonomy-Supported Errorful-Training

Much of the problem in many training environments, including medicine, is that we do not freely let learners commit errors and fail. We want to give them continuous opportunities to engage in errorless practice (‘perfect practice’). In medicine, this culture is evident and in turn, very problematic. However, engaging in task-specific (favourable) errors is beneficial to the learning process (Lee et al., 2016). In medicine, errors (i.e., medical errors) are considered to be very serious during independent practice and this fear of committing 'medical errors' may be shifted to early medical training, when it should not be. Training is dedicated time that should encourage trainees to commit errors, reflect on them and learn from them. Medical 'errors' and training 'errors' need to be separated. Perhaps encouraging errors during training would help encourage trainees to seek feedback and transform the feedback culture. Feedback does not need to serve as a motivator since medical trainees are already motivated (Archer, 2010). However, what novice medical trainees do struggle with based on the results of this dissertation is receiving below-average feedback. As Wulf and Lewthwaite (2016) have recently proposed in their OPTIMAL theory for motor learning, learners should be provided with autonomy-supportive learning environments. This proposition may not be entirely beneficial for highly-motivated learners like medical trainees, but what may be useful based on the dissertation findings is to provide novice medical trainees with a supportive environment to train with errors and receive authentic feedback.

5.4 – LIMITATIONS AND FUTURE DIRECTIONS

This dissertation has provided insight into the important relationship between motivation at the level of the individual and social-comparative feedback during motor skill acquisition in highly-motivated learners. The collective findings of this dissertation provide the first demonstration that highly-motivated learners like medical trainees interpret social-comparative feedback differently than non-medical learners. Novice medical trainees do not demonstrate additional learning benefits when receiving above-average feedback but are adversely affected by internalizing below-average feedback during the learning process. Although this dissertation provides novel findings that have both theoretical and practical implications, there are several limitations that are important to address. Specific limitations pertaining to each independent study are addressed in the discussion sections of Chapter 2 (for Study 1), Chapter 3, (for Study 2), and Chapter 4 (for Study 3).

One limitation for all the studies in this dissertation relates to sample size. This limitation has restricted some of the analyses, such as correlations, that could provide further insight into the intricacies of the complicated relationship between motivation and feedback. A second limitation is that trait motivation of the medical trainees was not measured throughout this dissertation. Rather, trait motivation was inferred from the motivational profiles of medical trainees that have already been established in the clinical education research. This measure was intentionally not taken during data collection since it was necessary to limit the number of psychological measures recorded in order to both minimize the chances of data contamination and to maximize the believability of the fabricated feedback. A third limitation for all of the studies relates to the lack of additional information that was recorded about the self-regulatory strategies that the trainees adopted during technical skill acquisition. For instance, the findings in Study 1 and 2 provide evidence that practice strategies were being modified (e.g., the use of the training videos and how many sutures were completed during practice); however, it is unclear how long and what parts of the video were re-watched and why, and how this may have impacted suturing acquisition. It would be important for future research to understand which strategies are being adopted, particularly after the delivery of negative social-comparative feedback, so that interventions can be designed to guide learners more effectively throughout the training process. A fourth limitation is related to the feedback itself. The fabricated feedback that was delivered to medical trainees was completely detached from their actual performance; however, it is interesting that the vague social-comparative feedback delivered throughout this dissertation was potent enough to modify psychological and behavioural outcomes across different phases of the learning process. Although this feedback was vague in nature, it is also interesting that trainees did not inquiry any additional information regarding the average (i.e., the actual performance score of the average) and how it may have been calculated.

Based on the results described in this dissertation, we are proposing that the negative social-comparative feedback is affecting *something* in the mind and that this modification is most likely occurring on a multidimensional level (e.g., impacting some type of change to a learner's mindset (i.e., to this *collection* of beliefs or emotions) that is then further having a significant impact on skill learning). Whatever is being altered by the social-comparative feedback is currently unclear and requires further research. The next line of research should also take a more multidimensional approach so that multiple lenses can be used to better understand the role that this type of feedback is having on this particular type of learner.

The next study in this program of research is exploring whether it is the relative or absolute negative feedback that is detrimental for novice medical trainees. In other words, this next study will examine if there are differences on outcome measures between negative social-comparative feedback and negative feedback. A follow-up study will also determine whether the detrimental effects of negative social-comparative feedback subside in senior medical trainees (i.e., once trainees have been immersed in the medical culture for a longer period of time and have had more diverse experiences related to feedback).

Future research should explore if the findings of this dissertation apply to other subsets of highly-motivated learners (e.g., professional athletes or other health professionals) or if they are specific to medical trainees.

5.5 – CONCLUDING STATEMENTS

This dissertation is composed of five original chapters that offer a critical and comprehensive overview of feedback, specifically social-comparative feedback, and its application to medical education. Collectively, this program of research provides the first demonstration that novice medical trainees (a subset of highly-motivated learners) interpret social-comparative feedback in a manner that is contrary to other learners studied in the literature. Based on these findings, adopting a better-than-average mindset does not provide added benefits to the learning process, whereas receiving below-average information, irrespective of task and feedback provider, is psychologically and behaviourally damaging to novice medical trainees. Once motivation at the level of the learner is taken into consideration, feedback interpretation and reactions contradict what has been found in the literature with non-medical learners. The findings from this dissertation have important theoretical and practical implications. Theoretically, the results provide consistent demonstrations that in order to understand the intricacies of feedback within a learning context, a person-centered approach needs to be considered. From a practical standpoint, the findings provide insight into the challenges of using social-comparative feedback in medicine. In all, findings of this dissertation are important to consider in both the context of feedback delivery and remediation as they provide evidence that novice medical trainees, regardless of the task and feedback provider, experience difficulty in receiving information that they performing relatively poorly compared to their peers. Feedback interventions in clinical education need to shift the focus to better understand how medical trainees can learn to mitigate (not avoid) receiving challenging feedback. Developing a better understanding of the *learner* will aid in more effective curricular designs and ultimately, more effective individual learning.

5.6 – REFERENCES

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APPENDIX A: STUDY MATERIALS

Appendix A.1 and A.2

Why are you currently engaged in this suturing activity?...

a) ...Because I think that this activity is interesting

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

b) ...Because I am doing it for my own good

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

c) ...Because I am supposed to do it

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

d) ...There may be good reasons to do this activity, but personally I don't see any

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

e) ...Because I think that this activity is pleasant

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

f) ...Because I think that this activity is good for me

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

g) ...Because it is something that I have to do

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

h) ...I will do this activity but I am not sure if it is worth it

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

i) ...Because this activity is fun

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

j) ...By personal decision

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

k) ...Because I don't have any choice

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

l) ...I don't know; I don't see what this activity brings me

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

m) ...Because I will feel good when doing this activity

1....................2....................3....................4....................5....................6....................7

corresponds	corresponds	corresponds	corresponds	corresponds	corresponds	corresponds
not at all	a very little	a little	moderately	enough	a lot	exactly

n) ...Because I believe that this activity is important for me

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

o) ...Because I feel that I have to do it

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

p) ...I will do this activity, but I am not sure it is a good thing to pursue it

1....................2....................3....................4....................5....................6....................7

corresponds not at all	corresponds a very little	corresponds a little	corresponds moderately	corresponds enough	corresponds a lot	corresponds exactly

---

<u>I have high self-esteem:</u>

1....................2....................3....................4....................5

not very true of me   very true of me

Appendix A.3

Using the following scale, please rate on a scale of 0%-100% how confident you are that you can successfully perform the upcoming suturing task:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Appendix A.4

Please answer the following questions based on your most recent suturing task.

MENTAL DEMAND: How much mental and perceptual activity was required (i.e., thinking, deciding, calculating, remembering, looking, etc.)?

0......10......20......30......40......50......60......70......80......90......100

not much at all	a moderate amount	a great amount

EFFORT: How hard did you have to work (mentally and physically) to accomplish your level of performance?

0......10......20......30......40......50......60......70......80......90......100

not hard	moderately hard	very hard

PERFORMANCE: How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

0......10......20......30......40......50......60......70......80......90......100

not at all	moderately	completely

FRUSTRATION LEVEL: How insecure, discouraged, irritated, stressed and annoyed did you feel during the task?

0......10......20......30......40......50......60......70......80......90......100

not at all	moderately	completely

Appendix A.5: Suturing Global Rating Scale

Total Score (/25)___________

Please circle the number corresponding to the trainee's performance in each category:

Respect for Tissue	1 Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments	2	3 Careful handling of tissue but occasionally caused inadvertent damage	4	5 Consistently handled tissues appropriately with minimal damage
Time and Motion	1 Many unnecessary moves	2	3 Efficient time/motion but some unnecessary moves	4	5 Clear economy of movement and maximum efficiency
Instrument Handling	1 Repeatedly makes tentative or awkward moves with instruments through inappropriate use	2	3 Competent use of instruments but occasionally appeared stiff or awkward	4	5 Fluid movements with instruments and no stiffness or awkwardness
Flow of Operation	1 Frequently stopped operating and seemed unsure of next move	2	3 Demonstrated some forward planning with reasonable progression of procedure	4	5 Obviously planned courses of operation with effortless flow from one move to the next
OVERALL PERFORMANCE	1 Very poor	2	3 Competent	4	5 Clearly superior

Appendix A.6: Suturing Specific Checklist

Participant # ____________

*Total Score (/20)*__________

Please mark the trainee's performance in each category:

Suturing	Done Correctly	Done Incorrectly
1. Hold needle driver properly (thumb and long/ring finger with index as stabilizer)		
2. Loads needle properly (at tip of jaws, 1/2 to 2/3 from point)		
3. Needle enters perpendicular to skin		
4. Equal bites on either side		
5. Passes needle through tissue without sawing, following curve of needle		
6. No gap between wound edges		
7. Wound edges everted		
8. First throw placed square, may be double throw		
9. Appropriate number of throws		
10. Appropriate tension on wound edges (does not tighten knot excessively)		