The Effect of Feedback on 3D Multiple Object Tracking Performance and its Transferability to other Attentional Tasks

Chiara Perico, School/Applied Child Psychology

McGill University, Montreal

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Abstract

Attentional processes play an integral role in learning, affecting performance on most cognitive tasks. In addition, feedback, defined as the instant information delivered to the individual that guides their subsequent behavior in relevant situations, plays a critical role in the efficiency and quality of learning. However, its effects are not often empirically assessed. Multiple Object Tracking (MOT) tasks can be used to objectively assess real world attention, and have been used as cognitive training paradigms geared at improving attentional abilities. With training, there is a significant improvement in MOT performance. However, little is known about the transferability of attentional capacities from MOT tasks to similar cognitive tasks. The goal of this study was thus to assess whether performance on attentional capacities acquired during training on a three-dimensional (3D) MOT task are transferrable to other measures of attention. The role of feedback was also investigated to determine whether performance, and its subsequent transferability to other measures, is affected by feedback. Forty typically developing adults participated in 4 testing sessions on consecutive days. On day 1 (or pretest session), intellectual and attentional abilities were assessed along with a baseline measure of MOT without feedback. Participants were then placed into 2 experimental groups and assessed for three subsequent days (days 2 through 4), with only one group received feedback during the MOT task trials; the other group received no feedback. On day 4, all participants were re-assessed on the same attentional measures as well as the MOT to determine improvements from day 1. MOT performance resulted significantly higher for the feedback group, as defined by an increased speed threshold for tracking 4 out of 8 items. The feedback group also revealed better transferability to other cognitive tasks. The results indicate that feedback is an important component during a learning regiment and that it may affect transferability of cognitive abilities.
Résumé

Processus attentionnels jouent un rôle essentiel dans l'apprentissage, affecter les performances sur la plupart des tâches cognitives. En outre, la rétroaction sur le rendement- l'information instantanée délivrée à la personne qui guide leur comportement ultérieur dans des situations pertinentes - joue un rôle essentiel dans l'efficacité et la qualité de l'apprentissage. Cependant, ses effets ne sont pas souvent empiriquement évalués. Tâches de suivi d'objets multiples (MOT) ont été développés pour évaluer objectivement l'attention du monde réel, et ont été utilisés comme des paradigmes d'entraînement cognitif visant à améliorer les capacités attentionnelles. Avec l’entraînement, il y a une amélioration significative de la performance de la MOT; cependant, peu est connu sur la transférabilité des capacités attentionnelles des tâches de contrôle technique pour les tâches cognitives similaires. L'objectif de cette étude était donc, d'évaluer si les performances sur les capacités attentionnelles acquises pendant l’entraînement sur une tâche MOT 3D sont transférables à d'autres mesures de l’attention. Le rôle de la rétroaction sur le rendement a également été étudié pour déterminer si la performance, et sa transférabilité ultérieure à d'autres mesures, est affecté par la rétroaction. Quarante adultes de développement typique ont participé à quatre séances d'entraînement pendant quatre jours consécutifs. Au jour 1, les capacités intellectuelles et d'attention ont été évaluées, aussi bien que une mesure de référence de la MOT sans rétroaction sur le rendement. Les participants ont été divisés en deux groupes expérimentaux et évalués pour trois jours suivants (jours 2 à 4): un groupe a reçu des rétroactions sur le rendement pendant les tâches essais MOT; l'autre groupe n'a reçu aucune réaction. Au jour 4, tous les participants ont été réévalués sur les mêmes mesures d'attention aussi bien que le MOT pour déterminer les améliorations du jour 1. Les performances après la formation sur MOT significativement amélioré pour le groupe de rétroaction, tels que définis par une augmentation du seuil de vitesse pour le suivi 4 sur 8 articles. Le groupe de rétroaction a également révélé une meilleure transférabilité à d'autres tâches cognitives/ Les résultats indiquent que la rétroaction sur le rendement est un élément important lors d'un régime d'apprentissage et qu'il peut affecter la transférabilité des capacités cognitives.
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Introduction

Background Rationale

During the course of each day, an individual is expected to attend to an extraordinary amount of visual information. Typically, real world visual scenes are complex in nature, involving multiple elements, both moving and stationary. In order to successfully navigate through such environments, the ability to track multiple objects at once is an extremely important asset. As an example, consider driving through a busy intersection at rush hour. Despite being a seemingly automatic task, it consists of the simultaneous processing of a multitude of elements that play a significant role in guiding the individual’s next course of action in an adaptive and secure manner. As a driver, one must pay attention to the surrounding cars, street signs, potential pedestrians and/or extraneous objects that could disrupt their physical space. In addition to these, one must take into consideration auxiliary elements that are not necessarily being attended to, but that are likely to render this scene difficult to navigate. For example, weather is likely to have affected most drivers; rain often impedes clear vision and snow or ice can affect the handling of the car, thus requiring more resources to be allocated on the driving itself, beyond the navigation of the visual scene. The ability to simultaneously attend to multiple salient aspects of a visual scene is referred to as multiple object tracking (MOT). One’s ability to track multiple objects is founded on the concurrent ability to inhibit non-salient stimuli, prioritizing relevant components (Scholl, 2009). As a driver, one is typically attending to other cars and street lights, while inhibiting less salient or distracting factors such as birds flying by or activities happening on the side of the road. The process of tracking salient objects as well as the ability to inhibit distractors requires selective and sustained attention, with attentional resources increasing with increased complexity of a visual scene (Doran & Hoffman, 2010; Drew, McCollough, Horowitz, & Vogel,
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2009; Feria, 2012; Howe, Drew, Pinto, & Horowitz, 2011; Scholl, 2009; Tombu & Seiffert, 2008). Considering the importance of MOT in everyday life, it is necessary to find ways to measure one’s attentional ability through methods that mimic real world scenarios. Thus, tasks were developed to determine one’s attentional propensity based on the ability to track a subset of moving objects within a dynamic visual scene. Characteristically of real world visual scenes, MOT involves selective and sustained attention to multiple objects, requiring varied attentional demands based on the amount of additional factors affecting the individual (e.g. fatigue, stress) or the presented scene itself (e.g. increased number of objects).

Chapter 1

Literature Review

How are multiple objects tracked simultaneously?

The first account explaining how multiple objects are tracked simultaneously was presented by Pylyshyn (1989), who proposed a theory of visual indexing. Prior to the idea of visual indexing, it was generally accepted that attention could only be directed to a single region in the visual field at once (i.e., attentional spotlight) (Treisman & Gelade, 1980), and that tracking moving objects occurred as a consequence of a rapid rate of attention movement (Pylyshyn & Strom, 1988). However, moving objects cannot be tracked by focal attention using a single stored description of each feature, because for visually identical targets, the only separating feature would be location. The problem is that the location of a moving objects is constantly changing and can often overlap with other objects, failing to explain successful multiple object tracking (Pylyshyn, 2001). As a result, Pylyshyn (1989) proposed that the visual system has a pre-attentive mechanism that individuates features and indexes their locations in a scene, allowing an individual to locate these features when necessary for further analysis. This
system is referred to as FINSTs (FINgers of INSTantiation) and is thought to provide a reference point for determining a target’s location (Pylyshyn, 1989). FINSTs can be attached to four to five targets which can be tracked independently and in parallel, maintaining their distinctive identity but without explicitly encoding their locations or recognizing their features; they are essentially a reference point in case further processing is needed (Pylyshyn, 1989). This theory was supported by later research indicating that if a target shape changed it was more easily recognized than if a distractor shape changed, demonstrating that the elements that were indexed were kept in better focus (Sears & Pylyshyn, 2000). Interestingly, Pylyshyn and Strom (1988) found that even when all objects were visually identical, subjects were able to track the targets as long as they were identified at the beginning of the task.

Further, Pylyshyn (2001) proposed that it is not the location of the target that is primary but rather the object to which the index, or property tracked, is associated. Objects seem to maintain individuality and separate spatiotemporal properties through motion, remaining indexed and thus being distinguishable in tracking tasks (Pylyshyn, 2001). This leads to the concept of object-based attention, wherein the basic unit of tracking is not a specific feature, but rather the object itself (Cavanagh & Alvarez, 2005; Doran & Hoffman, 2010; Pylyshyn, 2001; Scholl, 2009; Viswanathan & Mingolla, 2002)

Tracking demands

Despite the fact that target tracking is believed to occur pre-attentively, factors such as increased speed and distractor proximity and/or similarity, increase a tasks’ attentional demands by requiring more attentional resources for differentiation (Doran & Hoffman, 2010; Feria, 2012; Tombu & Seiffert, 2008). An object tracking task requires a participant to track a subset of moving objects for an extended period of time (Allen, McGeorge, Pearson, & Milne, 2006;
Tracking tasks are generally characterized by two separate phases: the acquisition phase and the object maintenance phase (Allen et al., 2006). During the acquisition phase, the targets are indexed and separated from the distractors, whereas during the maintenance phase objects are kept in focus by continually updating their location to maintain visual continuity of motion (Allen et al., 2006). Speed is crucial when conceptualizing tracking difficulty, as it is found to produce the same level of interference that a dual-task (a paradigm wherein an individual is required to perform two tasks simultaneously) produces (Tombu & Seiffert, 2008). Faster object motion increases the difficulty of discrimination between targets and distractors; as well it challenges one’s ability for continuous tracking throughout the task (Tombu & Seiffert, 2008). Faubert and Sidebottom (2012) emphasized the effect of speed on task dynamics, namely that the faster the movement, the larger the interaction between objects in the task, such as object collisions and crossovers. The increase of these events renders the tracking task more difficult to complete, by enhancing the amount of cognitive resources required. Furthermore, Faubert and Sidebottom (2012) also found that when the speed threshold at which the objects were moving exceeded an individual’s threshold, the movement was perceived as faster than it actual was, indicating difficulty in allocating cognitive resources beyond one’s capacity.

Conversely, distractor characteristics, such as proximity and similarity to targets, decrease one’s ability to successfully inhibit distractors and maintain focus on targets (Doran & Hoffman, 2010; Feria, 2012; Tombu & Seiffert, 2008). More specifically, proximity makes it more difficult to recognize boundaries between target objects and distractors, a key stage for object identification (Tombu & Seiffert, 2008). Similarly, physical salience of a distractor – or the degree of similarity to the target – will affect how well an individual will be able to
differentiate it from a target object. Feria (2012), determined that tracking tasks which included distractors that held more features in common with targets resulted in lower overall performance as opposed to tasks with more distinctive distractors. The increase in sheer number of distractors, regardless of their features, was also found to decrease tracking performance (Feria, 2012; Pylyshyn & Storm, 1988). These findings point to the influence that factors such as speed, similarity, proximity and task difficulty (e.g. number of targets and distractors) have on the allocation of attention and overall use of cognitive resources (Doran & Hoffman, 2010; Feria, 2012; Tombu & Seiffert, 2008).

**Multiple Object Tracking paradigms**

Multiple Object Tracking (MOT) paradigms are designed to assess participants’ ability to focus on and track a subset of moving objects with attention, over an extended period of time. This task is often considered the best empirical measure of real-world object-based visual attention (Scholl, 2009). In MOT tasks the items displayed are identical and targets are only briefly identified at the beginning of a trial by identifying (i.e., lighting up or cueing) the subset of items to be tracked (Scholl, 2009). The tracking task requires participants to follow the subset of items within a dynamic scene wherein the items move amongst each other within a defined physical space, in either two or three dimensions. In mimicking real world object tracking, items can become momentarily occluded, when they disappear behind other objects; however, since objects are expected to follow motion, participants can maintain tracking despite momentary occlusion (Pylyshyn, 2001). In fact, Viswanathan and Mingolla (2002) found that when three dimensional depth cues were present, thus showing a closer representation of a real-world visual scene, MOT performance was increased. Without depth cues, tracking of multiple objects was found to be more difficult, suggesting that depth cues allow for a quicker interpretation of whether objects moved in
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front or behind other objects, thus enhancing the understanding of motion continuation (Viswanathan & Mingolla, 2002). In sum, although the original idea of FINST is pre-attentive, tracking multiple objects can be a taxing task and require a large amount of effort and attention (Pylyshyn, 2001).

**Attention and MOT**

Multiple Object Tracking (MOT) paradigms require the use of various aspects of attention, where individuals must (i) divide their attention among the targets, (ii) select targets from non-targets, and (iii) maintain the tracked objects across spatial and temporal changes (Makovski, Vázquez, & Jiang, 2008). Scholl (2009) described the role of attention during MOT tasks in terms of three principal aspects; selectivity, capacity and effort. Scholl (2009) described the concept of selectivity as the manner with which certain stimuli are more easily processed than others. In particular, recent models of attention have emphasized the role of object-based attention, such as that used for MOT tasks, wherein the main unit of selection is not a single feature but rather the entire object (Doran & Hoffman, 2010; Pylyshyn, 2003). These models have highlighted that there are characteristics of objects that render them more easily distinguishable as an entity rather than a set of composing features; having closed boundaries is one such factor (Doran & Hoffman, 2010). Scholl (2009) explained the concept of object-based attention, affirming that boundary cohesion allows for better tracking and easier flow of attention, by relegating focus on a wider object surface rather than to a single point.

The second attentional concept of MOT is capacity, which refers to the limitation in amount of simultaneous processing that can occur. Previous research showed that one can concurrently keep track of 4–5 individual moving objects in a visual field (Allen et al., 2006; Pylyshyn, 2001; Viswanathan & Mingolla, 2002). However, as previously mentioned, there are a number of factors
that affect one’s capacity for object-based attention, such as the proximity and similarity of distractors.

The third attentional concept defined by Scholl (2009) is effort, which relates to the amount of cognitive fatigue that is produced following sustained tracking of multiple objects. Through the course of an MOT task, sustained attention is allocated to the indexes in order to prevent decay as a result of fatigue, in addition to being used for error recovery to ensure that objects are not lost while in motion (e.g., when being occluded). Factors such as increased duration, higher speed, increased number of targets and the individual’s current state have been shown to increase subjects’ fatigue, leading to a decrease in overall performance (Scholl, 2009). Interestingly, Scholl (2009) found a large amount of individual differences in relation to each of the above stated factors and how they impact subjects’ performance.

The amount of effort that an individual has to exert to complete a task is in direct relation to the task perceptual difficulty, also referred to as the task’s cognitive load (Doran & Hoffman, 2010). Doran and Hoffman (2010) highlighted that the cognitive load of a task will significantly affect how attention will be allocated. For a tracking task with low cognitive load (e.g., tracking two objects among a set of differently shaped/colored distractors), selective attention may not be required, as the tracking process may remain pre-attentive. However, with the increase of tracking difficulty, and thus cognitive load (i.e., more objects among similar or equal distractors), selective attention will be required to separate targets from distractors (Doran & Hoffman, 2010). Scholl (2009) suggested that MOT can be both pre-attentive and intentional, depending on both the cognitive load of the task (i.e., complexity) and the individual’s cognitive state.

The role of attention in MOT tasks has also been studied with the use of electrophysiological measures. For example, Drew et al. (2009) examined individuals’ electrophysiological responses
to either a target, a distractor or an extraneous object that was part of the background during the
course of a MOT task. Results demonstrated that targets elicited the greatest electrophysiological
response, followed by distractors and lastly by background objects. Drew et al. (2009) suggest that
the differential neural response was the result of a greater attentional engagement allocated to
targets during the tracking task, separating them from distractors or extraneous stimuli. They
further suggest that attention is distributed in correspondence to the salience of the object,
explaining the greatest response for targets, followed by distractors, as they interacted with targets
and needed to be attended to in order to discriminate them. Lastly, the least amount of stimulation
was provided by any extraneous stimuli present in the environment (Drew et al., 2009).

With the knowledge of attention being a significant component of performance on the
MOT task, studies have been conducted to determine ways to improve attentional ability with the
use of this task. As with most activities, consistently training on the MOT task - repeating the task
over several sessions - significantly improves one’s ability to track multiple objects, leading to the
development of MOT models used as part of cognitive training paradigms geared at improving
attentional abilities. For example, it has been demonstrated that training on the MOT task leads to
a significantly increased ability to track a larger number of objects, moving at greater speeds
(Faubert & Sidebottom, 2012), with increased performance interpreted as reflecting increasingly
efficient attentional abilities. For example, Faubert & Sidebottom, (2012) demonstrated that
athletes who trained consistently on a MOT task improved up to 300% on baseline MOT speed
thresholds. Considering the improvements in attentional ability shown with MOT tasks as a
consequence of training, it is important to address and further focus on, the factors that positively
affect performance. The most important factor enhancing attentional abilities is the process of
learning.
Learning

Learning and attention

Attention and learning are highly intertwined with one another, as attention is posited to focus the learning process while learning is expected to decrease the amount of attention required for a task (Dosher, Han, & Lu, 2010). There are two fundamental notions that symbolize the relationship between attention and learning. First, attention improves perceptual learning and it is expected that when attentional resources are allocated during a task, learning will occur at a faster rate, and vice versa (Dosher et al., 2010). Second, learning attained through continuous practice is expected to reduce the limitations that result from the confines of attentional capacity. Attentional capacity is reduced for tasks in which multiple elements must be followed at once. However, following repeated practice, the ease of performance increases as the need for attentional allocation decreases, suggesting that learning how to perform a task reduces the need for attentional resources (Dosher et al., 2010). Roelfsema et al. (2010) proposed that learning suppresses the attention allocated to irrelevant features of a task, allowing the key features to become more salient. In fact, perceptual learning is thought to occur through a process termed attention weighing, where more attention is posed to salient elements in a task, and less attention is given to distractor items. This allows more emphasis to be placed on the indexed objects and the tracking activity, while less importance is given to peripheral or task-irrelevant elements (Dosher et al., 2010).

Learning and MOT

As previously explained, performance on the MOT task improves with consistent training (Faubert & Sidebottom, 2012). As well, it has been established that learning attained through continuous practice can reduce the limitations that result from limits of attentional capacity and
enhance performance on a cognitive task (Dosher et al., 2010). These results have been replicated using the MOT paradigms, stemming interest in the role of learning in MOT tasks.

Jiang, Vázquez, and Makovski (2008) examined the relationship between attention and learning using a MOT task. They were interested in finding out what participants learned from the task, and specifically whether the learning process focused on the targets’ trajectories during motion. Target trajectories during motion were defined as the different directions that the objects were most likely to move; they posited that throughout training participants would learn some of the potential trajectories, thus increasing their readiness for tracking. Additionally, they were interested in determining whether learning was associated to temporal predictions, or rather the prediction of future target movements, hypothesizing that better prediction led to more successful tracking (Jiang et al., 2008). Results indicated that learning during an MOT task (as defined by increased performance over trials), does not result from an increased understanding of the objects’ motion trajectories, but rather from learning targets’ trajectories in relation to one another (Jiang et al., 2008). They also suggested that temporal prediction is not a key component of attentive tracking. They posit that individuals may be learning repeated motion trajectories within trials, and that successful performance in attentive tracking is a direct result of selective attention (Jiang et al., 2008). These results further indicate the intricate relationship between attention and learning, particularly within MOT paradigms.

*Learning and cognitive load*

Research has often attributed the progressive improvement in performance resulting from learning to be due to the task’s cognitive load. Cognitive load is defined by the amount of exertion that a task imposes on a learner, affecting the amount of mental effort, or the amount of cognitive resources, allocated to fulfill the task demands (Paas & Merriënboer, 1994). There are
two main factors that affect the perceived cognitive load of a task, namely the characteristics of
the task itself, and the cognitive abilities of the individual. However, these authors suggest that
more often than not, a combination of these two affects the cognitive load of a task (Paas &
Merriënboer, 1994). Specifically, novelty, time pressures, and reward systems can all be
considered as characteristics that affect the cognitive load of a task. These are coupled with an
individual’s subjective factors such as one’s criteria for optimal performance, motivation and
current state of arousal while performing the task (Paas & Merriënboer, 1994). A task with
higher cognitive load is associated with higher mental effort, and at least initially, with lower
performance. In fact, tasks that have high cognitive load are often negatively associated with
learning, because most of the available resources are allocated to performing the task and not
enough resources can be allotted to building meaningful connections to facilitate learning (Paas
& Merriënboer, 1994).

As will be discussed in the next section, a specific factor of interest within the realm of
attentional ability and learning is feedback. Learning is thought to occur with and without
feedback. However, it is suggested that feedback plays a significant role in the efficiency and
quality of learning, by providing the necessary information that can aid one’s performance on a
specific task (Hattie & Timperley, 2007; Kelley & McLaughlin, 2012; Roelfsema, van Ooyen, &
Watanabe, 2010).

**Feedback**

Feedback is defined as immediate knowledge of one’s performance (whether a response
was correct or not) on a task, or after individual trials during task completion (Hattie & Timperley,
2007). Feedback is proposed to affect performance through both affective (i.e., by increasing
motivation, justifying effort and enhancing engagement in a task) and cognitive processes (by
confirming correct or incorrect responses, restructuring understanding, and providing higher levels of self-awareness) (Hattie & Timperley, 2007). Feedback can be subdivided in four main levels based on what it is being provided; (i) for task completion, (ii) for the process used to complete a task, (iii) for self-regulation, and (iv) for personal achievement (Hattie & Timperley, 2007). Feedback about a task simply distinguishes correct from incorrect answers and is often referred to as corrective feedback. Feedback that is aimed at the process of task completion provides information on how to build a better strategy to improve performance. Self-regulation feedback addresses the way an individual monitors, directs and regulates his/her actions toward the ultimate task goal; in this case, the person’s own attributions about their abilities, success and failure are likely to play a large role on how they will perform. Lastly, personal feedback is often referred to as praise. However, this type of feedback directs the attention away from the task and to the individual and can sometimes have negative consequences (Hattie & Timperley, 2007).

One concern that is often present when devising tasks that include feedback is in determining the optimal amount and the ideal form of feedback to provide. Feedback can facilitate learning when used within specific learning contexts wherein it aims to address incorrect interpretations or misguided understandings, versus a complete lack of understanding (Hattie & Timperley, 2007). It is often argued that there are individual differences at play in the receipt of feedback and that certain personal characteristics render feedback more or less beneficial. Kelley and McLaughlin (2012) believed that optimal feedback is different based on the individual’s ability level in relation to the task demands. They found that individuals with lower cognitive resources benefit most from increased levels of feedback as it can free up resources (lowering cognitive load) to dedicate to the learning of the task; in contrast, individuals with higher cognitive abilities benefit most from less feedback as it facilitates complex
reasoning, which forces them to understand the task and improves their ability to perform on a retention test (Kelley & McLaughlin, 2012).

Types of Feedback

The provision of feedback can have different results based on the way it is administered. Hattie and Timperley (2007) determined that the most effective way to provide feedback is through the provision of cues or reinforcements, which are best delivered through video, audio, or computer-assisted instructional feedback. In contrast, they assessed that praise, punishment and alternative extrinsic rewards are the least affective since they can undermine intrinsic motivation (Hattie & Timperley, 2007). In addition, feedback is posited to provide the greatest benefit when task goals are specific and challenging, but overall task complexity is low (Hattie & Timperley, 2007). Specificity allows the participant to easily recognize where and why an error in response occurred, and how to improve subsequent responses (Hattie & Timperley, 2007). For example, Herzog and Fahle (1997) looked at different types of feedback administration to determine which is the most beneficial to task performance. Feedback was provided to participants in the form of an error signal for each incorrect response. They placed participants in different groups based on the type of feedback administration; these were either no feedback, trial by trial feedback (after each response), block feedback (after a pre-set number of trials), uncorrelated feedback (feedback administered at random trials), partial feedback (50% of the time), manipulated feedback (no feedback even when improvements were made), and reverse feedback (error signal for correct responses instead of incorrect). Their results demonstrated that in general, the provision of correct feedback significantly improved participants’ task performance, in contrast with reverse feedback or no feedback groups. In fact, they found that participants who were in the manipulated, partial or no feedback conditions showed slowed or little improvement across trials. However, these
groups also showed a large amount of individual differences (Herzog & Fahle, 1997). In addition, correct feedback was demonstrated to improve the rate of learning, delineated by faster performance improvements over time. Finally, corrective feedback also reduced individual differences among participants (Herzog & Fahle, 1997).

In another study conducted by Wilbert, Grosche, & Gerdes (2010), the effect of social comparison feedback, individual feedback, and criterial (or task-related) feedback were evaluated during the completion of a language learning task, wherein participants had to distinguish target words from distractors. Participants were additionally divided in high or low performing groups in order to determine whether feedback was used differently based on previous performance. Performance differences were also posited to highlight a difference in perceived self-worth, with those with low performance showing lower levels of self-worth (Wilbert et al., 2010). They found that task-related feedback was beneficial in increasing students’ focus. Interestingly, they found a difference between high and low performing participants, with low performing participants benefitting most from task-related feedback. It was proposed that low performing students are more sensitive to the negative effects of feedback as they are more likely to have a negative view of themselves as a result of their performance.

Generally speaking however task-related feedback was beneficial for both groups and prevented the shift from task performance to individual performance, thus solidifying the focus of attention on the task at hand (Wilbert et al., 2010).

Lastly, another important factor that affects the effect of feedback on task performance is its timing (Hattie & Timperley, 2007). Immediate correction of errors while the task is being performed was shown to result in faster rates of understanding and improvements. In a study looking at feedback used while learning new motor skills, it was found that those who received
Feedback and self-efficacy

As mentioned in the previous section, the benefits of feedback during learning are particularly relevant when taking into account perceived self-efficacy (SE), or perceived self-worth of an individual (Hattie & Timperley, 2007; Wilbert et al., 2010). Individuals with high SE are more likely to respond optimistically to feedback, whether positive or negative. On the other hand, low self-efficacious people tend to respond unfavourably to negative feedback, resulting in an overall decrease in motivation and task performance (Hattie & Timperley, 2007). The decrease in performance is often attributed to a higher likelihood that low SE individuals will reach learned helplessness at a faster rate, believing that they will not improve regardless of their efforts (Ilgen & Davis, 2000). The way that an individual perceives their own performance is often a result of an interaction between their actual task performance and their personal individual dispositions. The use of feedback is thus likely to be affected not only by the individual’s task performance but also by how they believe they performed; one of the key features that render feedback a useful tool to improve performance stems from the participant’s internal belief that they can play a role over their own performance (Ilgen & Davis, 2000). That being said, one way to target the role that self-efficacy exerts on performance is by framing the task on the basis of learning goals, or in other words stressing the gaining of knowledge or skill building, over evaluation of performance (Ilgen & Davis, 2000). Low self-efficacious individuals have a tendency to perceive tasks where the
improvements in performance is stressed, as more threatening because of the emphasis on competence and evaluation – which they expect to do poorly on. Learning goals on the other hand, emphasize the process of sequential learning and working toward the ultimate goal, relieving some of the pressure and allowing for the low SE individual to build confidence gradually (Ilgen & Davis, 2000).

Regardless of the type of feedback used to improve learning on a specific task, it is believed that once perceptual learning occurs, it can last for extended periods of time, such as months or even years (Roelfsema et al., 2010). However, there are contradicting accounts as to whether the effects of learning on one task are specific to the learned task (Roelfsema et al., 2010), or whether such beneficial effects can be re-allocated or transferred to tasks that involve similar cognitive functions. This knowledge would allow for the development of tasks that would target areas of cognition that require strengthening. These tasks would render learning more efficient as performance improvements would then affect a multitude of areas of the individual’s cognitive functioning.

**Transferability**

Considering the effects of learning and attention on task performance, and the fact that many cognitive tasks use similar underlying cognitive processes relying on both attention and learning, it is important to determine the ability of training tasks to influence the transferability of attentional capacities to other similar cognitive tasks. The importance of transferability lies in the ability to empirically measure whether a training task improves performance not only on the specific task being rehearsed, but also on whether it benefits all tasks that require similar cognitive skills (Jeter, Dosher, Petrov, & Lu, 2009). Jeter et al. (2009) argued against previous research findings that proposed that transfer is controlled by task difficulty, with easier tasks
showing higher levels of transfer than difficult tasks (Ahissar & Hochstein, 1997). These authors argued for a task precision theory stating that transfer is more likely to occur if the training task and the subsequent task to which transfer is tested are similar in requirements, or rather, task precision (Jeter et al., 2009). Jeter et al. (2009) found that task precision affected the amount of transfer from a training task to a transfer task, even when task difficulty (measured in terms of accuracy) remained constant between tasks and during learning. Interestingly, they also stated that transfer is affected by the initial difficulty of the training task, and that more transfer occurs when the transfer task is easier than the training task; on the other hand, transfer is stunted if the transfer task is more difficult (Jeter et al., 2009). Ultimately, results have demonstrated that transfer appears to be precision limited, and thus that the ability of a training task to allow for transfer of cognitive abilities is constricted by the transfer task used. Paas and Merriënboer (1994) also argued that schema acquisition during the process of learning a task is important because it facilitates better performance during a transfer task. This occurs as a result of overlap between schemas used for a training task and transfer task, with the increased practice on the training task strengthening the schema, leading to facilitated and ultimately improved performance (Paas & Merriënboer, 1994).

**Objectives of the Current Research**

With the use of MOT to assess attentional ability, it is increasingly important to determine what factors can be implemented to further strengthen one’s attentional capacity. Feedback is a factor that is often overlooked and seldom empirically tested within the realm of cognitive training, although it is universally understood to be beneficial to performance. As well, considering that attention is required for a variety of different cognitive tasks, understanding how improved performance using MOT tasks can affect other spheres of cognitive functioning is
paramount.

The present study thus had three main objectives. First, we aimed to determine whether the presence of feedback during the course of a MOT paradigm differentially improved MOT at multiple times of assessment. Second, we aimed to assess whether improved performance on a MOT task acquired during training sessions would transfer to other more traditional measures of attentional ability (i.e., the Continuous Performance Test (CPT)-II). Lastly, we wanted to find out whether or not the presence of feedback during the MOT training task would differentially affect the extent of transferability to the traditional, transfer task.

Hypotheses

It is hypothesized that training will improve attentional ability as measured by MOT performance [pre vs. post MOT] regardless of feedback condition (feedback vs no-feedback groups). However, if feedback is an important factor during learning, it is hypothesized that performance will be most improved for the feedback group. As well, it is expected that if feedback leads to a greater improvement in performance, it will additionally result in greater transferability from MOT to cognitive transfer tasks.

Chapter 2

Methods

Participants

Forty typically developing adults, between the ages of 18 and 30, participated in the present study (M = 23.3 SD = 3.36). Of these 40 participants, 13 were male and 37 female. Based on an intake interview participants were excluded from the study if they were taking stimulants or sedatives that would affect their attention; had a diagnosis of ADHD; history of seizure disorders; or conditions affecting their vision. In order to confirm general typical
cognitive status the Wechsler Abbreviated Scale of Intelligence was administered to all participants on the first day of testing. Participants were then randomly assigned to either Feedback or No Feedback groups. The Feedback group had a mean age of 23.15 years of age (SD = 3.17) and a mean WASI FSIQ of 112.1 (SD = 17.9). The no Feedback group had a mean age of 23.3 years of age (SD = 3.62) and a mean WASI FSIQ of 112.1 (SD = 17.9). Of the 40 participants, the data of two participants were omitted from analysis since they scored as extreme outliers (see Data Analysis section).

**Apparatus**

*Sony HMZ-T1 Wearable Head-mounted display (HMD)*

Since previous research found that self-motion can interfere with performance on the MOT task (Thomas & Seiffert, 2010), for the present experiment it was decided to immerse the participants in a virtual reality representation of the task, covering their entire visual field. For the purpose of this study, a 3D Multiple Object Tracking task based on the NeuroTracker platform ([www.neurotracker.net](http://www.neurotracker.net)) was used. The task was controlled using a laptop, and presented in three dimensions to each participant, using a Sony HMZ-T1 Wearable Head-mounted display (HMD). The HMD had a 3D display (increasing ecological validity) with 1280 x 720 display resolution and a field of view of 45 degrees, producing virtual image sizes of 150” at 12 feet distance. The virtual size of the spheres was between 20 and 55 mm (larger when they were in front of the virtual cube) and followed a linear trajectory in the 3D virtual space (see Figure 1). The HMD also has headphones to reduce surrounding distractions. The unit is extremely light-weight, weighing only 420 grams, which reduced discomfort to a minimum.
Stimuli

3D Multiple Object Tracking task

As shown in Figure 1, Participants were shown 8 spheres moving in a virtual volumetric space in different directions, and were asked to track 4 spheres during a 15 second trial. The spheres moved in a virtual cube with transparent virtual light blue walls. Each trial started with the presentation of 8 spheres positioned randomly in the 3D space (Figure 1-a). Four spheres then changed color (or indexed), representing those that must be tracked for the length of the trial (Figure 1-b) and were then set in motion (Figure 1-c). Once stopped, the participant told the experimenter which of the spheres (now numbered and all the same color) were tracked, and those spheres are subsequently lit-up (Figure 1-d). Finally, feedback is provided to the participant by “lighting-up” the correct spheres (Figure 1-e) after the participant’s response. During both the baseline conditions, and for the no-feedback groups during testing, feedback was not provided. If participants correctly tracked the target spheres for three consecutive trials, the speed of the moving spheres increased; they decreased if responses were incorrect. Two measures of performance were defined. The first was the maximum average speed threshold at which participants were able to track four of the eight items over the course of a session. The second was the highest speed at which participants were able to track four of the eight items within one session. The entire task lasted approximately 15 minutes.
Figure 1. Progression of a Multiple Object Tracking task using a NeuroTracker System with Feedback.

Assessment Materials and Questionnaires

Wechsler Abbreviated Scale of Intelligence (WASI)

For each participant, a baseline cognitive profile (i.e., IQ) was measured using the Wechsler Abbreviated Scale of Intelligence (WASI), to ensure participants had unremarkable cognitive abilities that fell within the average range for their age. The WASI is a brief measure of intelligence that can be administered to participants between 6-89 years of age, and takes approximately 30 minutes to complete. It consists of four subtests assessing verbal crystallized abilities (Vocabulary and Similarities) and non-verbal fluid abilities (Block Design and Matrix reasoning). The composite results of these subtests are calculated into scores of Performance IQ, Verbal IQ, and Full Scale IQ (FSIQ) (Canivez, Konold, Collins & Wilson, 2009).

Conners Continuous Performance Test II

The Conners’ Continuous Performance Test (CPT II) version 5 for Windows is a computer-based assessment of attention used to assess participants’ baseline levels of attention and post-test scores. The task requires participants to press the space bar every time a letter appears, except for the letter “X”. The speed at which the letters appear on the screen varies throughout the task. The task is 14 minutes long and is preceded by a short practice set (70 seconds) to make sure that participants understand the instructions prior to commencing the test.
The instructions appear on the screen informing the participants to press the space bar as quickly as possible for every letter that appears on the screen except for the letter “X”.

The CPT-II computer program provides a varied amount of data highlighting different facets of attention. These include measures of omissions (failure to respond), commissions (number of times participant pressed the space bar when the letter “X” was on the screen), hit reaction time (mean response time), attentiveness (defined as d’, or the ability to discriminate between targets and non-targets), standard error, etc. (Conners, 2000). For the present study, only measures of detectability, omission, and standard error will be considered, as they are expected to be most affected by improved attentiveness.

*New General Self-Efficacy (NGSE) scale*

Perceived self-efficacy was also assessed using the New General Self-Efficacy (NGSE) scale (Sherer et al., 1982). The New General Self Efficacy (NGSE) scale is an 8 item questionnaire, scored on a 5 point Likert-type scale (strongly agree-strongly disagree) that aims to determine differences in one’s own perception of their capabilities to meet task requirements in various situations (Sherer et al., 1982)

**Procedure**

All testing was conducted in a testing room of the Perceptual Neuroscience Laboratory for Autism and Development (PNLab), located in the basement of the Education Building at McGill University. Upon arrival at the PNLab, all participants were given a consent form, describing the scope of the research (see Appendix A for sample of consent form). Once the consent form was explained, read, and signed, cognitive assessment and training commenced. All participants took part in four testing sessions on four consecutive days; Baseline (Day 1), D2 & D3 (training sessions) and D4 (final training session and post-training assessment). During
D1, a cognitive profile was defined for all participants based on measures of (i) general intelligence using the Wechsler Abbreviate Scale of Intelligence (WASI) (Wechsler, 1999) and (ii) concentration using the Continuous Performance Test II (Conners, 2000). Perceived self-efficacy was also assessed using the New General Self-Efficacy (NGSE) scale (Sherer et al., 1982). Following cognitive assessment, a baseline measure of MOT performance was measured without the presence of feedback, for all participants. For D1, the cognitive assessments, self-efficacy questionnaire and baseline MOT tasks combined took approximately one hour to complete. For subsequent training phases (D2 - D4), participants were randomly assigned (n = 20) to either: (i) the MOT training group receiving feedback after trials, and (ii) the MOT training group receiving no feedback. Both groups trained for two consecutive days on the MOT task (D2 & D3). The MOT task lasted approximately 15 minutes. After these two days of training, they were re-assessed on the MOT task (D4) and the CPT-II, in order to evaluate the effect of cognitive training, and the possible differential effect of feedback on performance. Participants were compensated a total of 40$ for their participation at the completion of the study.

Chapter 3

Results

As mentioned in the procedure section, the dependent variables used in statistical analysis were speed threshold and highest speed, which reflected MOT task performance. Speed thresholds were calculated using a one up one down adaptive staircase procedure (Levitt, 1971). After a correct response (i.e., correctly identifying the 4 target spheres moving at a specific speed level), sphere speed displacement was increased by 0.05 log units and decreased by the same proportion after each incorrect response, resulting in a threshold criterion of 50%. The staircase
ended after eight inversions and the maximum average speed threshold was estimated by the geometric mean speed of the last four inversions. The speed threshold was therefore maximum speed of the spheres at which participants were able to perform correctly over the course of a testing session. The top speed variable was the highest speed during any trial during the session at which participants performed correctly. It is important to note here that the data of two participants were omitted from analysis since they scored as extreme outliers. The final number of participants used in analysis was therefore n = 38, with n = 19 for Feedback Group, and n = 19 in No Feedback group. To determine whether participants improved in MOT performance following four days of training in both speed threshold and top speed, a pre-post comparison was conducted; a percent increase in performance was calculated to determine the change in performance from D1 to D4.

**Change in MOT Performance: Feedback vs. No Feedback Groups**

*Speed Threshold*

An independent samples t-test was conducted to determine if a significant difference was present between Feedback and No Feedback groups following four days of training. A t-test, $t(36) = 2.34, p = .025$, revealed that the Feedback group had a significantly higher percent increase in speed threshold (M = 39.8%) from pre-test to post-test as opposed to the No Feedback group (M = 8.4%) (See Figure 2). Further analysis looking at each group individually, showed that the Feedback group significantly improved from pre-test to post-test, $t(18) = 4.03, p < .001$, whereas the No Feedback group did not, $t(18) = 0.61, p = .55$. 
Figure 2. Mean percent change in MOT Speed Threshold Following Training for Feedback and No Feedback groups. Error bars represent the standard error of the mean.

Top Speed

A t-test was conducted to evaluate whether a difference in top speed performance was present between Feedback and No Feedback groups following four days of training. The t-test revealed a non-significant group difference $t(36) = 1.654$, $p = .107$, indicating that percent increase in mean top speed reached, following four days of training, did not significantly differ between Feedback ($M = 41.4\%$) and No Feedback ($M = 18.1\%$) groups. However, the Feedback group reached a higher top speed than the No Feedback group after four days of training, despite not being significantly different (Figure 3). Further analysis looking at each group individually showed that the Feedback group significantly increased in Top Speed from pre-test to post-test, $t(18) = 3.67$, $p < .001$, whereas the no feedback group did not, $t(18) = 1.67$, $p = .11$. 
Self-Efficacy

To determine whether self-efficacy had an impact on MOT performance (i.e. percent increase in Speed Threshold), a correlational analysis was conducted comparing self-efficacy scores to the percent increase in MOT performance from pre to post test for both groups. However, self-efficacy did not appear to be correlated to MOT performance for either groups (Feedback, \( r(18) = .014, p > .05 \); No feedback, \( r(18) = .16, p > .05 \)). That being said the two groups had significantly different levels of self-efficacy at the start of training, \( t(36) = 2.083, p = .044 \). The Feedback group had a higher average level of self-efficacy (\( M = 34; Above\ average \)) than the No Feedback group (\( M = 31.7; Average \)).

MOT: Change in performance over training sessions

Although Change in performance was measured by calculating a percent increase in speed score for both groups between D1 and D4, we were also interested in the rate of change in
performance across the four days of training, as it would indicate the differential process of learning based on group differences. Within this context, learning was defined as the change in performance during D2, 3, and 4 of training, relative to D1. If both groups increased in performance across training sessions, then learning would be equally occurring among groups. However, a different pattern of performance relative to baseline would show the effect of feedback on MOT performance. In order to decrease inter-subject variable performance was normalized relative to D1 scores. This would render the rate of learning more clearly comparable between groups.

Rate of learning

A repeated-measures ANOVA was conducted to test whether speed threshold across four days of training differed among groups. The between subjects factor was group, either Feedback (n = 19) or No Feedback (n = 19). The within subjects factor was the day of training, with three levels according to the day of testing relative to baseline (Day 2, Day 3 and Day 4-posttest). The dependent variable was the improvement (i.e. % increase) in speed threshold relative to baseline. Mauchly’s test of sphericity was conducted to ensure that no significant differences existed between group variances. Mauchly’s test of sphericity was not significant, indicating that the assumption was not violated, $\chi^2(2) = 3.99, p = .136$.

Results from the repeated measures ANOVA (see Table 1) indicated a significant main effect of group, $F(1, 36) = 5.73, p = 0.022, \eta^2 = .644$.

Looking at the descriptive statistics, the Feedback group showed a higher percentage of performance improvement relative to baseline ($M = 37.91\%, SE = 9.07$) compared to the No Feedback group ($M = 7.2, SE = 9.07$). It can thus be inferred that Feedback had a positive effect on rate of relative performance from baseline to post-test. The repeated measures ANOVA did
not show significant main effects of Day ($F(2, 72) = 1.107, p = .336, \eta^2 = .03$) or an interaction effect ($F(2, 72) = .852, p = 0.431, \eta^2 = .023$) between group and day (see Figure 4). The means of performance improvement relative to baseline for both groups on each training day are represented in Table 1.

Figure 4. MOT performance increase (Mean percent change in MOT Speed Threshold) for each session relative to baseline for Feedback and No Feedback groups.

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Day of training relative to baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 2</td>
</tr>
<tr>
<td>Feedback</td>
<td>30.56 (13.73)</td>
</tr>
<tr>
<td>No Feedback</td>
<td>-6.02 (8.06)</td>
</tr>
</tbody>
</table>

Note. $N = 36$. 
CPT performance

Prior to analyzing whether transferability of cognitive abilities occurred between MOT performance and CPT, the change in CPT performance was assessed with pre- versus post-test comparisons. All CPT data scores were analyzed as T-scores, which represent the score of the individual taking the test compared to the population average, or the normative group (Conners, 2000).

Detectability scores were significantly different from pre-test to post-test for both Feedback, \( t(19) = -2.12, p = .047 \), \( M_{pre} = 48.80; M_{post} = 44.19 \), and No Feedback, \( t(19) = -2.17, p = .043 \), \( M_{pre} = 49.32; M_{post} = 43.77 \). However, the groups did not significantly differ from one another in terms of percent increase from pre- to post-test, \( t(36) = 0.373, p = .71 \).

Omission errors were not significantly different from pre-test to post-test for both Feedback, \( t(19) = -1.4, p = .176 \) and No Feedback groups, \( t(19) = .88, p = .386 \). As well, the groups did not significantly differ from one another, \( t(36) =1.19, p = .24 \). Error rate was significantly different from pre-test to post-test for the Feedback group, \( t(19) = -2.18, p = .042 \), \( M_{pre} = 43.54; M_{post} = 40.39 \) but not for the No Feedback group, \( t(19) = .616, p = .545 \), \( M_{pre} = 44.44; M_{post} = 46.24 \). The two groups did not differ significantly from one another in terms of percent difference from pre- to post-test, \( t(36) = 1.85, p = .07 \). However, the Feedback group showed a decrease in the percentage of error rate from pretest to post-test (\( M = -6.83\% \)) as compared to the No Feedback group whose error rate increased (\( M = 5.81\% \)), as shown in Figure 5.
Transferability

To assess transferability, three multiple regressions were conducted to determine whether MOT performance significantly predicted improvements on CPT measures of detectability, omissions, and error rate. For the present study, only these three measures of CPT performance were chosen as they are expected to be most affected by improved attentiveness. For each of the multiple regressions, the independent variables were group, percent increase on the MOT, and percent increase on the MOT by group.

Detectability ($d'$)

A multiple regression was run to evaluate how well MOT performance predicted the improvement in detectability on the CPT measure, following four days of training. Results
indicated that the predictors only accounted for 17% of the variance, which was not significant \( R^2 = .029, F(3,37) = .338, p = .738 \). Based on these results, MOT performance did not significantly predict participants’ improvement in detectability after MOT training.

**Omissions**

A multiple regression analysis was used to test if MOT performance predicted improvements in omission scores on the CPT task following four days of training. Results indicated that the predictors only accounted for 20% of the variance, which was not significant \( R^2 = .039, F(3,37) = .462, p = .711 \). Based on these results, MOT performance did not significantly predict changes in omission scores on the CPT task.

**Error rate**

A multiple regression was conducted to predict whether MOT performance affected the percent increase in error rate on the CPT task, following four days of training. Results indicated that the predictors accounted for 46.6% of the variance, which was statistically significant \( R^2 = .217, F(3,37) = 3.144, p = .038 \). The prediction was statistically significant for the independent variable of percent increase in MOT by group \( \beta = .342, t = 2.081, p = .045 \). As presented in the previous section on CPT performance pre vs. post-test for both groups, it was evidenced that the Feedback group decreased in error rate, whereas the No Feedback group increased in error rate, thus corroborating these results.

Based on the results obtained transferability seems to be occurring, however not across all measured of CPT performance.

**Chapter 4**

**Discussion**

The present study investigated the role of feedback during a MOT task to determine its
effect on improving individuals’ attentional abilities. As well, we sought to determine whether

the improvement in performance gained from training on a MOT task over the course of four
days, would reflect on other tasks that require similar cognitive abilities (CPT). Finally,
assuming that feedback would affect performance, it was a further aim of this study to determine
whether feedback could also affect the magnitude of transferability from the MOT task to the
CPT task.

**Summary of Results**

Results indicated that the Feedback group showed a significant improvement in
performance on the MOT, both in terms of *speed threshold* and *top speed* measures. In contrast,
the group receiving feedback did not significantly improve over the course of four days
(training). Participants’ self-efficacy - a personality attribute assumed to affect the reception of
feedback - did not appear to significantly correlate with MOT performance for either group.
Furthermore, the two groups showed a significantly different trend in relative rate of
performance increase (i.e., learning), with the Feedback group ultimately showing consistently
higher improvements on all three days relative to baseline scores as compared to the No
Feedback group. Finally, results suggest that MOT performance predicted the percent increase in
error rate on the CPT task following four days of training. To further analyze these results
together with the difference between groups in CPT error rate increase pre vs. post test, it was
evidenced that the group receiving feedback decreased in error rate following four days of MOT
training as opposed to the No Feedback group whose error rate actually increased. These results
suggest that some transferability occurred, evidenced by the increase in MOT performance
predicting a decrease in error rate on a similar cognitive task (CPT). Concurrently, however,
transferability did not seem to occur for other measures of CPT performance, namely
detectability or omissions.

**Feedback**

The main hypothesis that performance on the MOT task would be affected by the presence of Feedback was supported. Feedback on the MOT task, defined as the immediate confirmation of whether responses were correct or incorrect, helped to increase participants’ ability to perform on the task, exemplified by a significant difference between Feedback and No Feedback groups in the increase of Speed Threshold over the course of four days. Interestingly, groups did not significantly differ in Top Speed reached over the course of training. However, the Feedback group showed a significant improvement from baseline to post test, indicating that they were better able to track objects at higher speeds of motion. Speed is one of the factors that have the highest impact on a task’s cognitive load, with the increase in speed increasing the amount of effort required for completion (Doran & Hoffman, 2010; Paas & Merriënboer, 1994). Based on the present results, it could be suggested that feedback has an impact on facilitating learning, and thus decreasing the amount of effort - or a tasks’ cognitive load - needed to focus on moving objects at increasing speeds (Doran & Hoffman, 2010; Paas & Merriënboer, 1994).

Furthermore, looking at the present results and considering the effect of feedback on performance, it could be suggested that feedback leads participants to engage in self-regulated learning (Butler & Winne, 1995). It is likely that each participant applied specific strategies to complete the task, and feedback is an opportunity to monitor whether said strategies are working. With continuous monitoring and update of the current strategies, one becomes more competent at the completion of the task, thus improving overall performance (Butler & Winne, 1995; Hattie & Timperley, 2007). This is consistent with research looking at the relationship between feedback, self-regulated learning and cognitive processing, further establishing the importance of feedback.
THE EFFECT OF FEEDBACK ON 3D MULTIPLE OBJECT TRACKING PERFORMANCE AND ITS TRANSFERABILITY TO OTHER ATTENTIONAL TASKS

in task engagement, regardless of specific task characteristics (Butler & Winne, 1995).

The present task gave participants in the Feedback group the ability to consider the accuracy of their answers while performing the task; this provided participants the opportunity to perform more accurately by altering strategies as task completion was in progress. As evidenced by previous research, the results seem to confirm that trial by trial feedback is an efficient and effective method to provide feedback (Herzog & Fahle, 1997). By providing participants with the chance to update and monitor their strategies, feedback could also lower the amount of individual differences in task performance, by reinforcing correct approaches (Hattie & Timperley, 2007). The lack of feedback during a task of moderate difficulty, could results in self-doubt toward one’s response accuracy, leading participants to change strategies based on individual preferences; this would explain high individual differences and decrease in overall performance (Hattie & Timperley, 2007). Performance is thought to be affected by a person’s belief that potential success on the task is high; therefore, the lack of knowledge about one’s own performance can affect successful completion (Hattie & Timperley, 2007).

Self-Efficacy

In regards to Self-Efficacy, the lack of significant correlations between the participants’ perceived self-efficacy and their consequent performance, could have been a result of the type of feedback being used, namely task-related feedback. As previously described, task related feedback focuses solely on providing knowledge of correct and incorrect performance; it does not touch on the process the participant engages in to arrive at said response (Hattie & Timperley, 2007; Kelley & McLaughlin, 2012; Wilbert et al., 2010). In contrast, self-regulation feedback or personal feedback, are likely to be more sensitive to an individual’s self-efficacy, as personal attributes and feelings toward success and failure play a large role in these feedback
types (Kelley & McLaughlin, 2012). Also noteworthy is that both groups showed elevated self-efficacy scores; the lack of information regarding how those with lower self-efficacy would react to feedback makes it difficult to determine whether self-efficacy is an important attribute in the reception of feedback. Previous research has looked at self-efficacy by inducing either high or low self-efficacy in participants through exposure to either negative or positive verbal feedback; after this exposure the groups were shown to perform differently, with those in the high self-efficacy group performing better (Bouffard-Bouchard, 1990). This method could potentially allow for a further understanding of self-efficacy within the present research project, to determine whether self-efficacy does play a role in performance on cognitive tasks.

Attention and Learning

Results from the CPT measures indicate that participants in the Feedback group showed improved attention scores over the course of four days, as demonstrated by increase in detectability (d’) of targets and decrease in error rate. These results confirm previous research that evidenced the role of MOT in improving attentional ability, and furthermore, confirms the effect of feedback on performance (Faubert & Sidebottom, 2012; Hattie & Timperley, 2007; Makovski et al., 2008). As well, while looking at the relative rate of learning for both groups, it is evident that the Feedback group showed consistently higher performance improvement over the three days following baseline. Dosher et al. (2010), suggested that the relationship between attention and learning is reciprocal, with attention focusing the learning process and learning decreasing the need for selective attention. It can thus be suggested that feedback increased participants’ ability to focus on the learning process, resulting in faster learning, indicated by higher performance improvements for the Feedback group over training sessions. Moreover, the CPT measures show that participants are better able to discriminate between targets and
THE EFFECT OF FEEDBACK ON 3D MULTIPLE OBJECT TRACKING PERFORMANCE AND ITS TRANSFERABILITY TO OTHER ATTENTIONAL TASKS

distractors after four days of MOT training, which is consistent with the effect of training on the ability to discriminate between targets and distractors, as detailed in both Dosher et al, (2010), and Roelfsema et al, (2010). Engaging in attention weighing would have led participants to pay more attention to indexed targets, than to peripheral distractors (Dosher et al., 2010; Roelfsema et al., 2010); with increased attentional ability, attention weighing would have been most effective, as suggested by the Feedback group’s performance.

In addition, the improvement in performance could have resulted from learning the potential sphere trajectories, as was found in in Makovski et al., (2008). For example, knowing that upon sphere collision, the spheres are most likely to move in a certain direction in relation to how others spheres are also interacting with the targets would allow the participant to be more prepared and able to continue tracking the target objects with less difficulty (Makovski et al., 2008). Feedback plays a role in this learning process, by highlighting what learned trajectories were the ones that led to a correct response. Extirpating whether this is more related to attention, learning or feedback is difficult to say, but it certainly confirms the importance of considering each factor in relation to one another.

Transfer

The present study clearly established that perceptual learning occurred, determined by improved performance following repeated practice on the MOT task. However, the transferability of cognitive abilities from a training task to a similar cognitive task was not as clearly defined.

Results from the present experiment showed that receiving Feedback led participants to higher MOT performance, and lowered error rate during the transfer task - CPT. In a study conducted by Phye (1991), the effect of feedback during task performance, as well as its role in
transferring performance improvements to a separate task, were analyzed. Supporting the present results, Phye (1991) suggested that corrective feedback facilitates transfer, after determining that advice feedback or no feedback, were inefficient in doing so. Corrective feedback is thought to require participants to place a higher amount of effort to develop a general strategy that will overlap between training and transfer tasks; on the contrary, advice feedback provides participants with a potential strategy to be used, thus reducing expended effort, as well as learning. The increased effort on the training task renders participants better able to devise a strategy for correct completion, further strengthening the learning process; this would ultimately free attentional resources that could be allocated on solving a different task, or as in the present scenario, a transfer task (Phye, 1991). Relating this back to the current study and the concept of cognitive load, this would explain why the feedback group performed better on post-test CPT assessment. Improved performance on the MOT, as a result of learning and lessened cognitive load, would have improved participants’ ability to allocate a higher amount of effort to the transfer task, specifically to warding off errors.

That being said, considering the present results did not show transferability across the different measures of CPT performance, specifically in regards to attentiveness (or detectability, d1) it could be suggested that the four days of training on the MOT were not sufficient for transferability to occur in all realms (Paas & Merriënboer, 1994). Despite being enough training to show performance improvements they may not have been sufficient to solidify the attentional abilities enough, to transfer to other cognitive tasks. Further studies should investigate longer MOT sessions, and/or training for increased number of days to determine whether practice played a role in the amount of possible transfer.

The other reason that could have deterred successful transfer is the difference between
tasks. Despite the fact that both the MOT task and the CPT task are aimed at assessing attentional ability, Jeter et al. (2009) suggested that task precision affects the transfer of perceptual learning. They argued that task precision, or rather the match between tasks, will affect transferability. It could be suggested that the CPT task was not similar enough to the MOT task to show transferability under all domains. The MOT task is far more interactive and engaging; as well, participants get small breaks between trials. In contrast, the CPT task is a continuous 14 minute task, wherein participants must remain focused. As well, the lack of feedback on the CPT task could have affected performance, increasing the difference between tasks, stunting potential transfer of cognitive abilities.

Limitations

One limitation of the study was the way that self-efficacy data was collected. The New General Self Efficacy scale is composed of eight statements to be answered on a Likert scale from which a self-efficacy score is deducted (Sherer et al., 1982). As with all self-reported data, there is a potential for bias in participants’ answers. Participants were mostly university students and could also be more likely to have high levels of self-efficacy as well as above average IQ scores - as was the case for the present sample. As well, the main researcher was present in the room while the scale was being completed, which could have potentially affected the way participants answered. Lastly, age or gender differences were not examined.

Future Directions

Development

The present study focused on an adult population. However, it is obvious that attentional ability is related to developmental stage. In fact, the ability to efficiently use attention for cognitive tasks is congruent to the individual’s level of cognitive development, increasing in competence
with higher developmental stages (Ridderinkhof & Van der Stelt, 2000). These age-related improvements have been shown through many different tasks and it is suggested that one of the main reasons why such improvements are seen is due to the increased ability to sort through attentional targets; the time it took individuals to sort through selectively attended stimuli decreased as a function of age (Ridderinkhof & Van der Stelt, 2000). Additionally with increased age, children become better able to focus on relevant stimuli and spend less time processing irrelevant stimuli (Ridderinkhof & Van der Stelt, 2000). The value of assessing how attentional capacities, and their improvements with MOT paradigms, occur at different periods of development (children / adolescents / adults) is in its ability to provide the necessary information to foster and build on youth’s attentional ability. Increased knowledge on attentional capacity and potential for growth at different stages of development, can education to be targeted in its expectations, as well as in its interventions. Beyond education, clinicians can use this knowledge to devise appropriate treatment plans for conditions wherein attention is significantly affected (e.g., Attention Deficit Hyperactivity Disorder, Autism Spectrum Disorder, etc.).

Feedback

To further analyze the effect of feedback in the context of cognitive performance, it would be interesting to see whether other types of feedback would affect MOT scores differently. Assessing a variety of feedback types could shed light on what type of feedback is best received and it could help determine whether they affect perceptual learning differently; for example, using feedback that refers to the process of completion of the task, by giving participants hints on how to complete it, could further inform on the difference between performance feedback and process feedback (Hattie & Timperley, 2007; Kelley & McLaughlin, 2012; Wilbert et al., 2010). As well, it would help to point out which elements of feedback are
most effective for the completion of cognitive tasks.

It would also be interesting to determine how feedback affects the perceived enjoyment of a task since it is assumed to increase motivation and task engagement (Hattie & Timperley, 2007). Previous research has shown that if participants liked a task, they performed better, as enjoying the process built their motivation to complete it well (Smith, Gilmore, Berg, Smith, & Jameson-Charles, 2012). In addition, it would be useful to determine whether the presence of feedback in the MOT task specifically renders the task more enjoyable to complete; many participants in the No Feedback group, during completion of the study were curious as to how they performed, which suggests that knowing whether their responses were correct could have been rewarding.

Furthermore, considering the large amount of individual differences that were present among groups, it would be interesting to look further into associating cognitive styles and feedback. Bryant, Murthy and Wheeler (2009) worked on providing feedback based on individual predispositions in areas of perception, memory, processing style and thinking. They highlighted that at times, outcome feedback can be detrimental to task performance if the participant is unsure as to what to change on subsequent trials. With the addition of cognitive style feedback - or in other words, more personalized feedback - the individual would also be given an opportunity to reach self-insight leading to a stronger learning experience (Bryant et al, 2009). Bryant et al (2009), ultimately found that the combined provision of cognitive style feedback and outcome feedback led to higher performance than either outcome or cognitive style feedback alone. This type of research would be most beneficial when working toward using MOT tasks for inclusion in schools. If teachers were implementing these tasks, they could add important feedback based on knowledge of their pupil’s personalities and cognitive abilities, thus
improving overall performance.

Given the effect of feedback on overall performance, it would be valuable to determine whether the perceived difficulty of the task was different among groups, and most importantly whether this changed over the course of four days. Looking at a comparison relative to baseline, which should theoretically be equally challenging for both groups, would potentially shed more light on the role of cognitive load in MOT tasks. It would be interesting to test cognitive load across the four days of training to determine whether participants felt a difference in the amount of effort expended. In addition to understanding the role of cognitive load, measuring perceived task complexity would inform on the best time to implement feedback and whether more practice is necessary prior to its introduction. Ilgen and Davis (2000) found that task complexity is affected by individual differences and particularly that participants’ attributions can affect perceived difficulty and concurrently the reception of feedback – rendering it either beneficial or detrimental. Being able to adjust the amount of practice necessary to render groups equally receptive to feedback based on attributions, could facilitate learning and strengthen attentional abilities (Ilgen & Davis, 2000).

Transfer

To further assess the role of transferability in connection with the MOT task and the presence of feedback, it would be interesting to determine whether tasks that are more similar to the MOT task would show greater levels of transferability, further strengthening the arguments present in Jeter et al. (2009). It would further be interesting to determine what type of similarity is required for transfer to occur, whether it’s based on task dynamics (e.g. motion, objects or task specifications) or whether it’s more fundamentally focused on the cognitive abilities that are most important for task completion. However, if it is the latter, the type of cognitive abilities
used would need to be further specified, as different levels of cognitive abilities could be required for different tasks; for example, some tasks are likely to require more memory than attention, and vice versa, and determining each task’s specific needs to render them similar enough for transfer would be an important step toward widening the understanding of transferability.

Transferability has a far reaching implication in the field of education, specifically for individuals with disabilities. The ability to strengthen a cognitive ability through the use of tasks such as MOT, and have its improvements transferred to tasks that require similar cognitive abilities that were below average level of performance, would provide for a potentially revolutionary way to remediate deficits.

**Conclusion**

The present study has highlighted the importance of feedback in cognitive training, while providing empirical evidence for its ties with learning and attention. Furthermore, the results have shown that there is potential for the transferability of improved cognitive abilities using a MOT paradigm, to other spheres of cognitive training.
THE EFFECT OF FEEDBACK ON 3D MULTIPLE OBJECT TRACKING PERFORMANCE AND ITS TRANSFERABILITY TO OTHER ATTENTIONAL TASKS

Appendix A

18+ Consent Form

Institution: Faculty of Education, McGill University

Title of Project: Training the brain to learn using an automated attention task - the role of feedback, development and perceived self-efficacy.

Project Leader: Armando Bertone, PhD

Applied/School Child Psychology
Department of Educational and Counselling Psychology
Faculty of Education, McGill University

Chiara Perico, MA candidate
Education and Counselling Psychology
Faculty of Education, McGill University

Introduction: We are interested in improving our knowledge of how individual’s attentional capacities develop. In particular, we are interested in assessing how cognitive training and feedback affect the ability to pay attention. We will do so by measuring your ability to track multiple spheres presented via special goggles that you will wear. We are also interested in assessing whether obtaining feedback after a response increases your attentional ability. The information obtained by this study will be used to further our understanding of how cognitive training using a computerized task will impact your ability to concentrate and pay attention to information. Additionally, we will further acknowledge whether your perceived self-efficacy (a person’s beliefs of their own ability to do well on a task) has an effect on how feedback is perceived. Consequently, this knowledge will facilitate our interpretation of how improved attentional abilities on this task can be transferred to other life domains.

The study will be carried out in the Faculty of Education at McGill University. Although the research findings will be disseminated at scholarly conferences and in the writing of scientific articles, results from individual participants will remain strictly confidential.

Procedures: The study will be carried out over a 4 day period. On the first day (Day 1), the visit will begin with a series of cognitive assessments involving computerized tasks targeting attention, concentration and problem-solving skills. This will be followed by a computerized multiple object tracking (MOT) task. You will be asked to sit comfortably while wearing a head-
mounted display (goggles) and respond to a visual task that will be presented to you. The task will involve looking at a number of moving spheres and track a number of them; then you will be asked to tell us which were tracked. These tasks are very simple, but are sensitive enough to help us understand the development of your attentional processing. You will also be asked to complete a questionnaire providing information that will complement our findings.

This first visit will take approximately 1.5 hours and will be punctuated with as many breaks as you need. You will then be asked to repeat only the MOT task for the following two days (Day 2 & 3) at our lab; we can arrange to assess you at your domicile if necessary. These training sessions will take approximately 15 minutes to complete. Finally, on the last day of training (Day 4), you will be asked to complete the MOT task for a final time, in addition to the other tasks completed during Day 1. This final session will last approximately 1 hour.

**Advantages of the proposed study:** There is no other direct advantage from your participation in the present study other than your contribution to the advancement of scientific knowledge regarding how attentional abilities develop during typical development. Although the results obtained from the multiple object tracking tasks have no diagnostic value, a better understanding of how attentional abilities can improve with training and how they can be transferable to multiple domains will be able to guide the development of efficient age-specific learning approaches, methods and tailored materials.

**Disadvantages of the proposed study:** There are no known side-effects associated with the previously described visual and/or cognitive tasks.

**Confidentiality:** All the information will be kept confidential, except as required or permitted by law. You will be assigned a study number and the information will be filed using this unique identifier code. Only this code will link the participant to the sample. The principal researcher can only perform the decoding of the data or an individual authorized by the former. Therefore, apart from Dr. Bertone and the principal investigator, only members of regulatory agencies or members of the Research Ethics Board may have access to the data. If data from this study is published or presented at scientific meetings, personal identity will never be revealed. All of the information will be kept confidential, except as required or permitted by law. Data obtained from this study will be stored until the completion of the principal investigator’s thesis defense, after which it will be rendered completely anonymous through the deletion of any identifiers that would allow for the participant to be retraced.

**Participation:** Participation is voluntary. You may refuse to participate or withdraw from the study at any time without any prejudice to your future involvement with McGill University. In the case that you do withdraw from the study, all previous data collected will be destroyed.

**Incidental Findings:** Although your cognitive and behavioral findings are clinically non-interpretable (i.e., used for diagnosis), any questions regarding your performance will be
explained to you, upon your request.

**Compensation:** You will be compensated a total of 40$ for your participation at the completion of the study (or have a choice of a gift certificate of equivalent value i.e., Indigo/Cinema Guzzo etc). Participants completing one to three of the sessions (in the case of attrition) will be compensated 10$ per session completed.

**Contact Numbers:** If you have any questions about the research, please contact Dr. Armando Bertone at the Faculty of Education at (514) 398-3448 or armando.bertone@mcgill.ca.

If you have any questions or concerns regarding your rights or welfare as a participant in this research study, please contact the McGill Ethics Officer at 514-398-6831 or lynda.mcneil@mcgill.ca.

**Declaration of the participant:**

In signing this consent form, I recognize that all aspects of the study have been explained to me, and that I understand the study. I also agree that I have had the opportunity to ask questions about the study, and that all my questions have been answered satisfactorily.

I, __________________, have read the above description with one of the investigators, __________________. I fully understand the procedures, advantages and disadvantages of the study, which have been explained to me. If you want to participate please sign below.

________________________
References


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