Perceptual Dual-Task Training via Simulation for Veterinary Students

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Perceptual training can be implemented via simulation for specific tasks in which the actual event being trained for rarely occurs. Simulation may also be able to train domain-specific skills related to stress-management difficult to train in real-world training. Simulation use is growing wide-spread in the training of the motor skills used in similar tasks, but generalizability of perceptual skills and abilities to specific tasks is not clear. The current study sought to examine the potential of a veterinary training simulation module and examine the relationship between training methods and working memory capacity, and these factors effects on performance in a stressful, dual-task perceptual performance environment.

Veterinary students, like all medical students, learn a wide variety of skills and procedures as part of their training. Due to advances in graphic and processing capabilities of standard computers, it is now both possible and convenient to employ simulation in the training of these students to help them learn to process specific stimuli and arrangements of stimuli corresponding to specific procedures. Perceptual training via simulation holds many advantages over more traditional 'real world' training for certain types of tasks. First, with the wide variety of tasks that must be learned for veterinary students, it is logistically difficult to introduce students to all of the different types of procedures they will encounter and skills they will require as professionals. Exacerbating this logistical difficulty is that many procedures occur rarely, so when they do occur viewing opportunities are in high demand. To accommodate the needs of all the students would lead to overcrowded operating rooms and a diminished benefit to any particular student observing the procedure. Through the use of simulation training for procedures of this nature, students can achieve familiarity with the stimuli and events related to different procedures, and develop the skill sets needed to navigate such procedures.

Bokhari et al (2010) designed and validated a simulation training tool to aid medical students in developing skills in laparoscopic surgery using the Nintendo Wii™ and found that students assigned to train their fine motor skills via an off-the-shelf game for the Wii console transferred this motor training to make fewer errors in an electrocautery task than did their control group counterparts, showing that in the domain of motor skills, general training may lead to improved performance on specific medically related tasks. The study showed that training of general motor skills may transfer for medical students to enhanced motor skills in medical procedures.

While many of the procedures and skills performed by medical and veterinary students alike share certain characteristics, such as motor abilities and use of visual and spatial working memory, it is unclear whether cognitive and perceptual abilities transfer as well between domain-specific and domain-general contexts as motor abilities do. Two perceptual/cognitive skills important in medical and veterinary training are perceptual categorization of stimuli and stress/attention-management. Research suggests that general visual working memory and change perception may not transfer from general ability to specific procedures. In a study by Beck, Martin, Smitherman, and Gaschen (2012), the researchers tested the perceptual ability of veterinary students at varying levels of experience and veterinarians to detect changes in radiological images and their ability to detect changes in everyday scenes. The results suggested that the critical factor in enhanced ability to detect changes in radiological images was 'eyes-on training' with domain-specific images, but found that this enhanced domain-specific skill did not translate to enhanced perceptual skill in change detection in everyday scenes. The data from a second experiment showed that veterinary faculty outperformed faculty from other domains and novice undergraduates on a similar change detection task, but that within the group of veterinary faculty members, amount of experience did not predict better performance, suggesting that change detection for this specific skill was acquired through 'eyes-on training', but reached a plateau thereafter. The results from this study indicate that interaction with the stimuli specific to a given procedure is paramount in acquiring skill in a given procedure, at least in tasks involving visual working memory, so training the ability itself, while certainly not detrimental, would not be likely to enhance performance in the context of interaction with specific stimuli. This study involved a relatively standard skill for veterinary students, reading a pair of radiological images. As mentioned before, some procedures occur infrequently, so 'eyes-on' training is inherently difficult in such cases. The use of simulation could offer this training at a much diminished cost of both time and effort for veterinary training programs.

One possible drawback of simulation training is the difficulty in reproducing stress caused by dynamic attentional demands in real procedures. It may seem intuitive that learning under a stressful state would benefit performance under a similar stressful state, but stress often inhibits learning and performance in tasks that require divided attention and/or working memory (see LeBlanc, 2009 for a review). LeBlanc proposed in her (2009) review that medical practitioners may wish to consider training medical professionals in stress-management.

Coping with stress tends to be related to appraisal of the situation and the individual's perception of their own abilities and available resources (Mathews & Campbell, 2009). Since coping with stress is a critical factor in surgical performance (Wetzel et al, 2010), training the skills used during surgery and the ability to accurately appraise and conserve resources may be a useful means to train stress-management practices conducive to learning and performance. In this regard, simulation training may offer a benefit to veterinary training in addition to the cost and convenience factors. Since actual veterinary procedures are, in some cases, rare and, in all cases, time- and safety-critical, training via simulation may be able to induce learning of domain-specific perceptual skills that are likely to transfer to real procedures while also training cognitive and task related appraisal of resources that would be difficult to train in the context of a live procedure.

One method of training that may be implemented via simulation and holds the potential to aid in stress-coping is part-task training (Wightman & Lintern, 1985). This method involves training users in parts of a task to enhance performance on the entire target task, or 'whole-task', such as training the perceptual categorization aspect of a veterinary procedure. Training the perceptual categorization of stimuli relevant to a specific veterinary procedure in a part-task environment may free up resources during actual performance of the procedure, thereby enhancing stress- and attention-management strategies during the procedure, despite the novelty of the stressful multi-task environment.

A second training method, emphasis-change training, promotes enhanced task exploration during training: training different task elements under varying priorities will better equip the learner to appraise needs and resources during performance and allow the learner to acquire skill strategies under varying skill priorities, while avoiding the learning-inhibitory effects inherent in training the whole task, which may cause stress or overload (Gopher, Weil, & Siegal, 1989). Emphasis change training is a dual-task training paradigm, making it suitable for training the perceptual tasks involved in veterinary procedures which will often be accompanied by engagement in other tasks simultaneously. The method involves training a target or primary task to be completed accompanying a secondary task. The two tasks are completed under varying differential priorities (e.g. primary 80% - secondary 20%, primary 50% - secondary 50%, primary 20% - secondary 80% effort) in addition to being trained with 100% effort given to each task individually. The nature of the method leads to generally lower performance during training compared to singular part-task training due to increased attentional demands, but leads to improved long-term learning gains as well as enhanced transfer to performance later on due to the simultaneous training of the part-task under varying attentional demands (Yechiam, Gopher, & Erev, 2001). This method would seem especially suitable in the case of tasks that are performed in high cognitive workload situations.

Another cognitive ability pertinent to these different training methods is working memory capacity (WMC). WMC, understood here as the ability to hold relevant information in working memory while dealing with or ignoring irrelevant or intrusive information (see Copeland et. al., 2005, for a discussion of WMC and some ways of measuring it), may modulate the effectiveness of different training strategies. For example, individuals with low WMC ability may have difficulty in a dual-task scenario for different reasons than individuals with high WMC, so training method may interact with WMC.

Overview of the Experiment

We aimed to train the perceptual skill of quickly classifying the quality of the placement of a lead wire used in balloon valvuloplasty heart surgeries for dogs by taking steps to determine the relationship between different training methods and individual differences in WMC, and evaluate the effectiveness of brief exposure and classification of stimuli on perceptual learning in a dual-task scenario. Balloon valvuloplasty heart surgeries involve the insertion of a lead wire in to the heart of a canine, followed by the threading of a catheter tube over the lead wire with a balloon attached. The balloon is then inflated, loosening a stenosis in the canine heart, allowing for regular bloodflow.

In the current experiment we examined part-task and emphasis change training methods compared to a 'pure' dual-task training scenario. In this dual-task training method, users are trained to perform two tasks together. The primary task involved the classification of a series of lead wire images extracted from a video of a veterinary surgery as either 'good', 'fair', or 'poor', based on the likelihood that different lead wire placements would cause problems during surgery. These images were classified via expert consultation with practicing canine cardiologists. The secondary task was a 1-back task, implemented via a StarCraft II map variant. In this tasks, participants were to indicate with a key press when the same unit crossed the screen twice in a row.

It was expected that participants in the part-task training and emphasis change training conditions would outperform those in the other condition across the experiment with an equal amount of time spent training. It was expected that WMC would affect the efficacy of different training methods, but no specific hypotheses were held regarding the nature of this relationship.

Method

Participants

Twenty-one undergraduate students were recruited from a large Southeastern University for participation in return for either satisfaction of a curriculum requirement for an introductory psychology course or for extra credit in a cognitive psychology course. Mean participant age was 21.19 (*SD* = 2.46), with 11 males and 10 females.

Materials

All participants engaged in a total of 2 computerized tasks during the study, and completed 3 additional computerized ability tests: A lead wire classification task, a 1-back task using a StarCraft II map variant, an automated operation span task, an automated symmetry span task, and a computerized digit symbol substitution task, in addition to a demographics form and a brief exit survey.

Classification task. The lead wire classification task involved the classification of 9 lead wire stimuli in to categories of 'good', 'fair' and 'poor' lead wires. These stimuli were contrast enhanced radiological images extracted from a video of a surgical monitoring computer during a canine balloon valvuloplasty procedure. The nine stimuli were extracted from the video to fit in to the three categories based on the likelihood that the lead wires would cause complications (i.e. heart palpitations or tissue damage) during the surgery via expert consultation with veterinarians.

Participants classified the nine stimuli 3 times though in random order for each block, resulting in blocks of 27 trials. The lead wire would be displayed to the participant for 2.3 seconds during which the participant could use the keyboard to classify the lead wire. After the 2.3 seconds elapsed, the participants would receive feedback on the correct category for the given lead wire. This feedback would remain on screen for 1.2 seconds and was followed by a 1.0 second mask of random dots before the next trial would begin with presentation of a new lead wire. After each block of 27 trials, participants would see how many lead wires they correctly classified out of 27, and this 'running score' was available to the participant during each block. Each block of trials would run for about 122 seconds.

In the later stage of the study, participants would complete 1 block of this same task in a retention test, except all feedback was removed, shortening the block from about 122 seconds to about 91 seconds. The participants also completed a near transfer test in the later stage of the study, during which they classified 3.0 second video clips from the original video of the surgical monitoring equipment using the same criteria. During this near transfer task, participants classified each of nine videos three times each in random order for one block of twenty-seven stimuli, having 2.3 seconds to respond to each video after the 3.0 second video clip had finished playing, followed by a 1.0 second mask between trials. The transfer block lasted about 172 seconds. The timing of each trial was based on pilot testing data on a very similar task from a previous study.

N-back secondary task. The 1-back task was implemented via a map variant of the StarCraft II video game. This task involved units moving across the screen one at a time, and the participant was instructed simply to press a key on the keyboard to 'shoot down' any unit that crossed the screen twice in a row. Blocks of trials on the StarCraft II 1-back task (n-back task) were timed to last the same amount of time as each stage of the lead wire task since the tasks were performed concurrently. Participants were instructed that they would be penalized for misses and false alarms, were given block feedback on their performance during acquisition, and no feedback on their performance during retention and transfer.

Ability tests. Two automated complex span tasks were administered. These tasks involved either being presented letters between completing simple math problems then recalling the letters in order (automated operation span task), or being presented with light locations on a grid between making vertical symmetry decisions then recalling the grid locations presented in order (automated symmetry span task). The former measures the ability to hold pertinent verbal information in working memory while dealing with distractors, and the latter measures the ability to hold pertinent spatial information in working memory while dealing with spatial distractors. The two tasks were automatically presented and scored via automated E-Run programs obtained from the Attention and Working Memory Lab at Georgia Technical University in Atlanta, GA (see Conway et al., 2005 for a review of complex-span tasks and measuring working memory capacity). These span tasks were used to measure WMC to determine the extent to which participants were able to hold information in working memory, both verbal information (automated operation span task) and spatial information (automated symmetry span task).

A measure of perceptual speed was also obtained using a computerized digit symbol substitution test (DSS) obtained from the Cognitive Aging and Technology Lab at Clemson University." This measure showed no relationship with performance in the dual task environment, and will not be discussed further.

Design

Between-subjects variables included training type (dual-task training [DTT], dual-task emphasis-change [DTEC], part-task training [PTT] and WMC (lower, higher). A within-subjects variable of Stage was included (acquisition, retention, transfer).

In the DTEC condition, participants completed five blocks of trials during acquisition, completing the lead wire classification task and n-back task together. On any given block, participants were told either to split their attention and effort in one of five ways between the two tasks, 100% n-back and 0% lead wire, 80% n-back and 20% lead wire, 50% / 50%, 20% / 80%, or 0% / 100%. The order of these blocks was counterbalanced across participants in two subsections, with the first two blocks always being the 100%/0% and 0%/100% blocks, and the three 'dual-task' blocks being counterbalanced between blocks 3, 4, and 5.

In DTT, participants completed five blocks of trials during acquisition, completing the lead wire classification task and n-back task together. Participants were told to devote half of their attention and effort to each task for every block.

Participants in the PTT completed 2.5 blocks of each task separately during acquisition, to keep the overall acquisition time constant between conditions. Participants completed one half block (14 stimuli block for lead wire classification task) and two full blocks of the lead wire classification task and the n-back task separately.

Dependent variables included performance on the lead wire task and performance on the n-back task across each stage of the experiment (acquisition, retention, and transfer).

Procedure

After providing consent, participants were randomly assigned to one of three different training methods and performed the acquisition blocks, which varied based on training condition as explained in the study overview. Then participants completed a computerized demographic form, the digit symbol substitution task, and the two span tasks. First, participants completed a short dual-task warm up block, lasting about 45 seconds. Next, all participants completed a dual-task retention test, instructed to spend half of their effort and attention on each task, and to do as well on both tasks as they could. Participants then completed a very near transfer task, in which participants were instructed to use the same criteria they had used on the lead wire classification so far, but that they would now be classifying 3.0 second video clips of lead wires. These video clips were from the same video that the static stimuli were extracted from. Finally, participants completed a single-task retention test of the static lead wire stimuli, before filling out a short exit survey and debriefing. In the retention and transfer phase, all participants completed the lead wire classification task and the n-back concurrently, with all performance feedback removed.

Results

Before analysis of scores on the lead wire classification task during acquisition retention and transfer, all participants were divided into high and low categories of WMC based on their normalized and combined scores on the automated operation span task and the automated symmetry span task. Participants were then divided via a mean (0) split into two groups, 11 participants in the higher WMC group and 10 participants in the lower WMC group. Between conditions, there were 4 higher and 3 lower WMC group members in the DTEC and PTT conditions and 3 higher and 4 lower WMC group members in the DTT condition.

To determine if there were differences between conditions and WMC groups on accuracy on the lead wire classification task during acquisition, a univariate ANOVA was conducted. It is important to note that these are different measures between different conditions due to the nature of the three training conditions. In the DTEC condition, the acquisition score for any participant was accuracy on the lead wire classification task during the 50/50 block in which participants were to divide their attention and effort equally between the two tasks. This block of trials was either in the 3rd, 4th, or 5th block, depending on the particular counterbalance of any given participant. The acquisition score for participants in the DTT condition was the accuracy on the lead wire classification task during the 4th of 5 blocks, since this was the average block in which DTEC participants would complete the 50/50 block of trials. The acquisition score for the PTT participants was simply the 3rd and final block that these participants completed, but these participants were classifying the lead wires in a single-task environment, unlike participants in either of the dual task conditions. There were no significant main effects for training type or WMC group on the lead wire accuracy scores during acquisition, nor was the interaction between training type and WMC group significant.

To evaluate performance on the retention and transfer tests, RM-ANOVA's were conducted first on N-Back task scores, then on lead wire classification task scores.

N-back scores were computed as (correct - false alarms) / (correct + misses). A 3 x 2 x 2 mixed-model ANOVA was conducted with between-subjects factors of Training Type WMC group, and Stage. No significant main effects or interactions were found.

Lead wire. To determine if there were training type and WMC group differences on lead wire classification accuracy during retention and transfer tests, a 3 x 2 x 2 mixed-model ANOVA was conducted. Between-subject factors included Training Type, WMC group, and Stage. A significant within-subjects effect was discovered for testing stage, F (2, 30)=8.80, η_p^2=.37, p = .001. Bonferroni corrected comparisons revealed that transfer test scores were significantly lower (M = .62, SD = .14) than dual-task retention test scores (M = .71, SD = .18), p = .012, and single-task retention test scores (M = .73, SD = .14), p = .006.

The test also revealed a significant condition x working memory group between-subjects interaction, F (2,15)=5.12, η_p^2=.41, p=.02, prompting a univariate analysis. There was a significant effect of WMC group within the DTT condition, F (1,25)=5.04, η_p^2=.25, p=.04, and within the PTT condition, F (1,15)=5.76, η_p^2=.28, p=.03. Within the DTT condition, higher WMC group participants (M = .73, SD = .10) outperformed lower WMC group participants (M = .54, SD = .15) across testing stages. Also in the PTT condition higher WMC group participants (M = .80, SD = .09) outperformed lower WMC group participants (M = .60, SD = .06) across testing stages (Figure 1). Interestingly, in the DTEC condition, lower WMC group participants (M = .79, SD = .04) outperformed higher WMC group participants (M = .66, SD = .14), though non-significantly, p = .132.

Univariate analyses also revealed a significant effect of Training Type within the lower WMC group (F (2, 15) = 4.79, η_p^2 = .39, p = .025). Bonferroni corrected comparisons revealed that within the lower WMC group, participants in the DTEC condition (M = .79, SD = .04) significantly outperformed participants in the DTT condition (M = .54, SD = .15), p = .025.

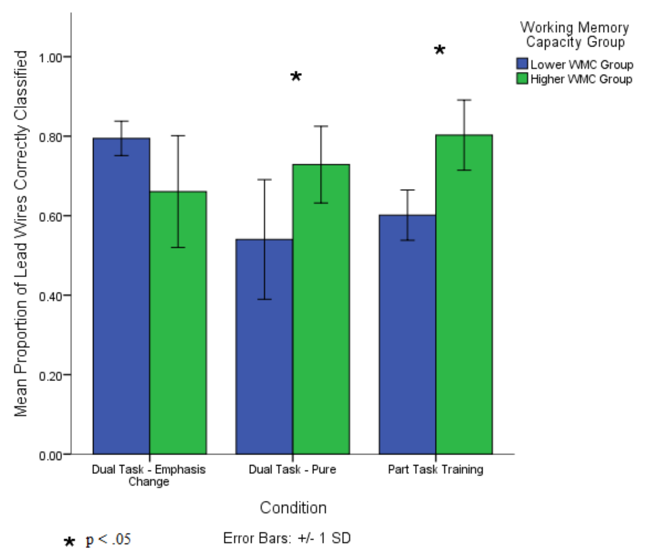

Figure 1. Lead wire accuracy by condition and WMC group

Discussion

The results of the current study indicate that part-task training is more beneficial to those with higher WMC, while dual-task training with emphasis change is more beneficial to participants with lower WMC. One reason for this may be that participants with lower WMC are less proficient at holding relevant and crucial information in working memory during dual-task performance, and likely benefited from the practice of performing each task at different priority levels to make strategies for maintaining performance on each task in times that the task is emphasized (i.e., 80% effort), as well as in times when each task is de-emphasized (i.e., 20% effort). Individuals with higher WMC are likely already more proficient in this skill, and benefitted from the practice of each task individually in the part-task training method because they were able to become optimally familiarized with each task, suffering relatively less than their lower WMC counterparts with the addition of a dual-task environment.

The low performance on the transfer task supports the notion that eyes-on training with domain-specific stimuli is the critical aspect of perceptual learning (Beck, Martin, Smitherman, and Gaschen 2012), indicating the importance of tailoring training methods, whether part-task or whole-task, to the specific stimuli that will be encountered during 'real-world' performance.

It is important to note that the two WMC groups used in the current study represent a post-hoc split of a relatively homogenous sample. The current sample does not reflect individuals with 'clinically' low WMC or high WMC, and only represent a split between 'lower' WMC and 'higher' WMC within the current sample of undergraduate students. In future studies, it would be interesting to determine if the effects found in the present study, added benefits of emphasis change training among low WMC individuals and benefits of part-task training among high WMC individuals, would be exacerbated in a more clinical population.

Additionally, the benefits of part-task training and emphasis change training may have been diminished in the current study. Participants in the part task condition saw half as many stimuli in each task than their dual-task counterparts. Similarly, participants in the emphasis change condition went through two blocks (100/0, and 0/100) in which one task or the other was completely de-emphasized, though it was still running in their visual field. These participants also only engaged in one block of equal (50/50) divided attention, the same instruction for all participants in the retention and transfer tasks. Given these potential shortcomings, it is surprising that these two conditions seemed to outperform the dual-task pure training condition with such a small sample ($n = 21$, 7 per group), and such a brief training time (about 15 minutes total including practice and instruction). Future studies should seek larger and more diverse samples, and consider lengthier training protocols, especially given research by Gopher and colleagues (e.g. Gopher et al., 1989), indicating initially low performance from emphasis change training, with higher long-term retention rates.

The current study identifies two key components in dual- or multi-task training and performance, the ability to 'home-in' on the critical aspects of a given psychomotor task, and the ability to quickly retrieve these aspects in attention under both high and low task loads. Taken together, these two aspects of psychomotor dual task performance aid in stress-management during performance by freeing up cognitive resources for coping and appraisal during performance. To further validate this claim, it would be useful to collect stress and workload information for individuals in different training methods throughout acquisition and performance, to determine if in fact any one training method leads to lower workload during dual-task performance, and if different training methods aid in reducing workload more or less in individuals with differing WMC.

Engaging in the parts of a task under different priorities (i.e. emphasized or de-emphasized) can aid in the ability to attend to only the most important aspects of each task, possibly freeing up resources for stress-management strategies of coping and appraisal, but only in cases in which the benefits of dual-task attentional strategies outweigh the benefits of familiarization with each part of the task (in the current study, for individuals with lower WMC).

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