Drawing with Your Eyes: Comparable Memory Benefits for Oculomotor and Manual-motor Drawing

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Abstract
Drawing pictures of to-be-remembered target words leads to better memory than does writing them. In the current study, we sought to better understand the relative contribution of the hand-motor movement component of this drawing benefit. Participants encoded, and later recalled, a set of words in each of three intermixed encoding trial types. For the draw and write trial types, participants drew or wrote out the target word on a tablet computer, respectively. For the eye-draw trial type, participants used purposeful eye movements to 'draw' a representation of the target using eye-tracking technology. Participants remembered significantly more words that were drawn and eye-drawn than written at encoding, replicating the drawing effect. However, there was no significant difference between words drawn compared to eye-drawn, signifying that manual and ocular motor movement confer comparable memorial benefits. These findings provide evidence that drawing as an encoding tool is as flexible as it is potent.

Résumé
Le geste de dessiner des mots cibles dont on doit se rappeler favorise davantage la mémoire que l'acte d'écrire ces mots. Dans cette recherche, nous voulions mieux comprendre la contribution relative de la composante liée à «l'acte moteur de la main» dans l'avantage du geste de dessiner. Les participants devaient d'abord encoder une série de mots dans chacune des trois séries types d'encodage mixtes, puis se rappeler ces mots. Pour les séries de type «dessin et écriture », les participants devaient dessiner ou écrire le mot cible sur une tablette électronique. Pour les séries de type «dessin par motri-cité des yeux», les participants utilisaient la technologie du suivi du regard et se servaient de mouvements oculaires de manière intentionnelle pour «dessiner» et offrir une représentation du mot cible. Les participants se rappelaient beaucoup plus les mots qu'ils avaient dessinés à la main ou avec les yeux que ceux qu'ils avaient écrits au moment de les encoder, une duplication du geste de dessiner. Cependant, les différences entre les mots dessinés à la main et les mots dessinés à l'œil s'avéraient non significatives, ce qui signifie que l'acte moteur de la main et les mouvements oculaires confèrent des avantages comparables pour ce qui est de la mémoire. Ces résultats démontrent que le dessin en tant qu'outil d'encodage se révèle aussi flexible que puissant.

Past studies have aimed to discover methods by which we can prolong, strengthen, and preserve our sometimes fleeting recollections of the past. Recently, Wammes, Meade, and Fernandes (2016) provided evidence that creating drawings of to-be-remembered information is a particularly effective encoding strategy. They postulated that drawing improves memory by enabling a seamless integration of elaborative semantic, motor, and visual aspects of a memory (see also Wammes, Jonker & Fernandes, in press). The purpose of the current study was to determine the importance of manual hand-motor movement in producing the benefit of drawing on subsequent memory. If manual hand-motor movement is indeed an important part of the drawing process, removing it should diminish any subsequent memorial boost. Testing this notion necessitated the development of an entirely new encoding task – eye-drawing – which removed the manual-motor component of drawing while attempting to hold other aspects of the task constant.

The 'drawing effect' refers to the reliable finding that creating drawings of to-be-remembered information improves memory (Wammes et al., 2016). This is evident in younger and older adults (Meade, Wammes & Fernandes, 2018), and across many paradigm variants (reduced encoding time, Wammes et al., 2016; different stimuli, Wammes, Meade & Fernandes, 2017; alternate test formats, Wammes, Meade & Fernandes, 2018). Even preparing to draw without actually drawing improved memory (Wammes, Roberts & Fernandes, 2018). Other groups have shown similar effects in free recall (Paivio & Csapo, 1973), with scenes, nonsense figures (Peynircio□ lu, 1989), flags (Blake & Castel, 2019), and educational materials (Van Meter & Garner, 2005). It is clear that drawing is a potent tool for improving memory and learning, but the mechanisms driving this effect remain uncertain.

Aspects of the three components thought to be critical to drawing-related memory benefits have each been studied on their own in great detail. Specifically, the generation (better memory for self-generated relative to provided words; Slamecka & Graf, 1978), enactment (better memory for physically enacted relative to read words; Cohen, 1981), and picture superiority effects (better memory for pictures relative to words; Paivio, 1971) – analogous to elaborative, motor, and pictorial components, respectively – have been studied at length in the field of psychology. Theoretically, drawing requires the interactive use of all three of the aforementioned mnemonic strategies simultaneously. That is, while engaged in drawing, motor systems are used to move the hand, generative processes are required to think about how to draw the item, and visual/pictorial feedback is provided by the drawing itself.

In the current experiment, we aimed to measure the relative influence of the hand-motor component of drawing-related memory benefits. Eye-tracking technology was employed to allow participants to create drawings using one's eye movements instead of hand movements. This encoding strategy was designed to incorporate only two of the hypothesized factors contributing to the drawing effect (pictorial and elaborative), while selectively removing the third (manual-motor). The idea being that as components thought to be important to the drawing effect are selectively removed, the memorial benefit that follows should be attenuated. Therefore, our first prediction was that participants would better remember target words that were encoded using 'eye-drawing' relative to 'writing', but that eye-drawing would not reach performance levels as high as 'drawing'. Memory for eye-drawn items may, however, still approach the levels of performance observed in hand-drawing because of additional oculomotor processing, and potentially increased novelty or distinctiveness of the task. Our second prediction was that we would replicate the observed benefit that drawing affords memory: words that were drawn compared to written would be better remembered (for a review, see Fernandes, Wammes, & Meade, 2018).

Although we had no *a prioi* predictions about the number of saccades made during eye-drawing, we conducted an exploratory analysis to determine if they had any relation to subsequent memory for a given trial. The prediction is that, insofar as motor movement in general is critical to the drawing effect, those participants who engaged in more eye movements (as quantified by number of saccades) should exhibit larger benefits of eye-drawing.

Method

Participants

Based on sample sizes used in previous drawing effect work, we set a minimum recruitment goal of 30 participants (e.g., Wammes et al., 2016, Experiments 1 and 4). In the end, thirty-six undergraduate students (27 female) were recruited through the University of Waterloo's undergraduate pool for psychology course credit. Participants ranged in age from 18 to 24 years (M = 19.75, SD = 1.73), and all self-reported having learned English before the age of nine, as well as having normal (non-corrected) vision.

Materials

We selected 36 concrete, high frequency nouns (log 1n transformed CELEX; M = 3.14, SD = 1.30), of average length (characters; M = 5.33, SD = 1.95), and having low object visual complexity (estimated by the file size of digitized referents, measured in KB; M = 14,393.30, SD = 10,265.62; Szekely et al., 2004) from the International Picture Naming Project (IPNP). The experiment was designed using custom scripts embedded within proprietary Experiment Builder software, and utilized an EyeLink 1000 unit for eye-tracking (SR Research Ltd., Ottawa, ON). Hand-drawing and writing trials were performed using an Acer 10.1" touchscreen tablet screen with a stylus.

Procedure

Following informed consent, participants first completed a task to determine eye dominance to facilitate eye-tracking with the infrared (IR) camera. For all tasks, the participants' heads remained in a chin rest to maintain position facing the eye-tracking unit.

During a practice phase, six words (two of each encoding trial type) appeared in random order, preceded by one of three encoding instructions: draw, write, or eye-draw. Participants were given 15s to complete the task, for each word. In the draw and eye-draw trials, participants were instructed to continue drawing until time was up, adding detail if they finished early. For the write trials, participants were asked to write out the word repeatedly until time ran out.

Following practice, participants were shown 30 target words, one at a time, in a randomly intermixed order (10 words randomly chosen per trial-type). These appeared in five blocks of six words, with a mandatory 15s rest period and re-calibration of the eye-tracker between each block. Instructions and timings were identical to the practice phase.

Following this encoding phase, participants completed a two-minute tone classification task in which they were told to identify whether a presented tone was low (372 Hz), medium (498 Hz), or high (624 Hz) using a button-press on a keyboard. The purpose of this task was simply to introduce a filled retention interval prior to the memory test, allowing learned material to transition into long-term memory. Participants were then given two minutes to freely recall aloud as many words as they could remember from the study phase.

Results

Part 1: Overall Recall Performance

Before any formal statistical analyses began, we sought to first identify and remove univariate outliers (> 3 *SD*), however none were detected. Therefore we proceeded by conducting a repeated-measures ANOVA with trial type (draw, eye-draw, and write) as a within-participant factor, and proportion of words recalled as the dependent variable. Assumptions regarding normality and sphericity were met and therefore no corrections were implemented. There was a significant main effect of trial type, $F(2, 70) = 17.09$, $MSE = 1.90$, $p < .001$, $\eta_p^2 = .33$. Simple effect contrasts revealed that recall was higher for words drawn ($M = .41$, $SD = .17$) relative to written ($M = .25$, $SD = .17$) at encoding, $F(1, 35) = 22.27$, $MSE = 3.91$, $p < .001$, $\eta_p^2 = .39$, and higher for words eye-drawn ($M = .43$, $SD = .14$) than written, $F(1, 35) = 34.86$, $MSE = 3.06$, $p < .001$, $\eta_p^2 = .50$. The was no difference in recall between words drawn and eye-drawn at encoding, $F(1, 35) = 0.23$, $MSE = 4.43$, $p = .64$, $\eta_p^2 = .01$ (see Figure 1 for means).

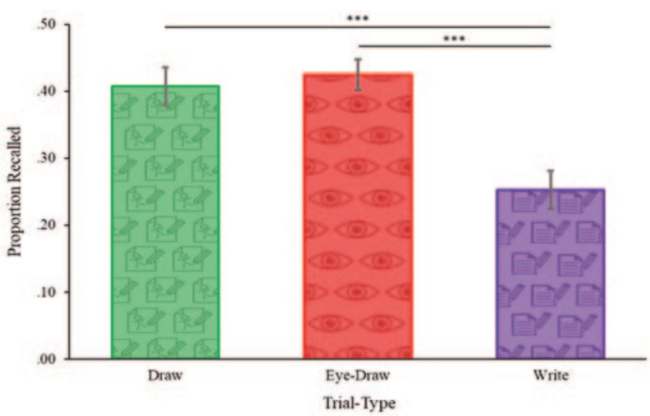

Figure 1. Proportion of target words recalled, following draw, eye-draw, and write encoding instructions. Error bars represent the standard error of the mean. *** = $p < .001$.

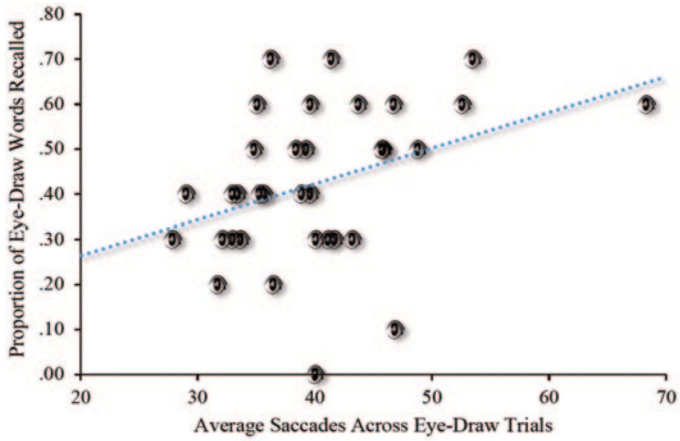

Figure 2. Proportion of words recalled that were eye-drawn during encoding was positively correlated with number of saccades on eye-draw trials. Trendline is a linear fit.

Part 2: Exploratory Saccade Analysis

Saccade data from two participants were not available due to technical errors with the eye-tracking unit. The average number of saccades participants made during eye-drawing trials was found to have a positive correlation with the proportion of eye-drawn words recalled, $r(34) = .37$, $p = .03$. After removing an outlier based on number of saccades (> 3 *SD*), the pattern of results remained largely the same, though the correlation between number of saccades and proportion of eye-drawn words recalled was now only marginal, $r(33) = .34$, $p = .06$.

Discussion

In this study, we sought to gain a better understanding of the relative contribution of multiple encoding factors on subsequent memory. Participants remembered significantly more words that were drawn and eye-drawn than written at encoding, suggesting that writing is a less effective encoding strategy than the former two. There was no significant difference in memory performance between words that were drawn compared to those eye-drawn, suggesting that comparable memorial benefits are conferred by manual-motor and by the unique implementation of oculomotor movement necessary for the eye-drawing task. Our results replicate the drawing effect (Fernandes et al., 2018; Meade et al., 2018; Wammes et al., 2016, 2017, 2018). In addition, this study is the first to show that eye-drawing at encoding is an effective encoding technique that provides a significant memorial boost relative to writing.

Our initial prediction was that words drawn at encoding would have led to the highest level of recall, followed by eye-drawing, and then writing, because each on the surface invoked three (elaborative, motor, and pictorial), two (elaborative and pictorial), and one (motor) of the critical component(s), respectively. Our results suggest that while the beneficial effects of hand-drawing may be driven in part by the contribution of manual-motor movement, eye-drawing is capable of producing similar memory performance. However, one important limitation is that the eye-drawing task may differ from hand-drawing in more than just the type of movement required. For example, it likely differs in its relative difficulty (Bjork, 1994) and novelty (Kishiyama & Yonelinas, 2003; Tulving & Kroll, 1995) relative to hand-drawing, both of which are known to contribute to memory performance (see Appendix A for trial examples).

The memorial benefit gained by eye-drawing could also be due to the addition of a unique oculomotor contribution that compensates for the missing manual-motor process typically included in normal hand-drawing. For example, research has shown that the number of eye movements (i.e., saccades) one makes at encoding is positively correlated with their subsequent recognition memory for images (Loftus, 1972), as well as visuo-spatial working memory performance (Pearson, Ball & Smith, 2014). Taken together, the foregoing studies indicate a tight coupling between oculomotor and memory systems, which may play a critical role in determining what is later remembered. Consistent with these general ideas, when eye movements at encoding were explicitly linked to to-be-remembered targets in the current work, memory performance was substantially better than our writing baseline condition. Moreover, while the correlation between saccades and recall for eye-drawn words was only marginal, the trend towards a positive association suggests that eye-drawing could be a useful task for pursuing the links between eye movements and memory. Future work should explore the degree to which eye movements alone can enhance memory retention.

Conclusion

The current study was the first to show that a new novel task of 'eye-drawing', during encoding, was able to boost memory relative to writing, and was even on par with drawing, a powerful and robust active encoding task. We have shown that oculomotor movements used to depict the to-be-remembered items are as effective as using one's hands to draw such items. Therefore, the immediate implications of the current study stem from the promising resiliency that drawing seems to offer as an everyday mnemonic strategy. While the current results suggest that other 'types' of drawing can result in similar memory benefits as normal hand drawing, further studies are required to identify underlying mechanisms that can explain why drawing is such an effective technique to improve memory. Given the current demonstration of the robustness and flexibility of drawing-related memorial benefits, future research in this domain appears fruitful.

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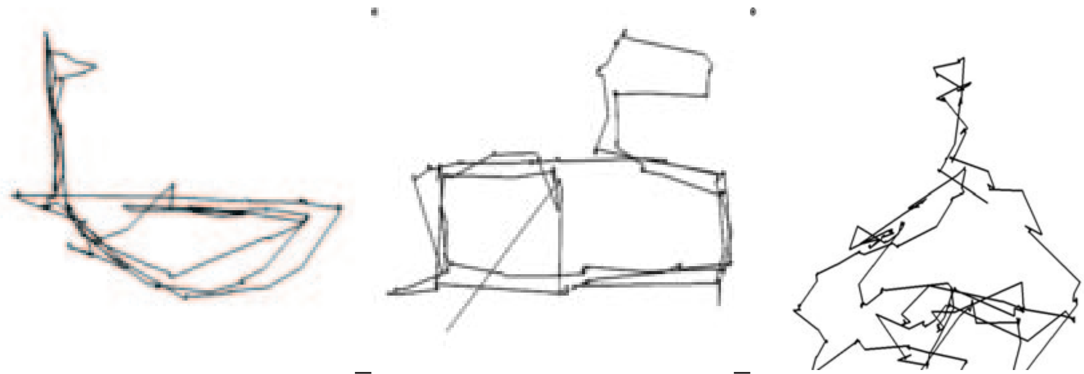
Appendix A.

Samples of hand-drawn, eye-drawn, and written productions by participants for the target word 'boat'.

Draw

Eye-Draw



Write