Exhibition of 'the Drawing Effect' Across VARK Learning Preferences in High School Students

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ABSTRACT

In a free-recall experiment, the presence of 'the drawing effect' in relation to VARK learning preferences was examined in high school students. Participants were asked to draw and write out a list of presented words and afterwards completed a questionnaire to identify their VARK learning preferences. There was no statistically significant difference between the number of written words recalled versus the number of drawn words recalled. Further, no relationship between VARK learning scores and the drawing effect was identified. This experiment indicates that high school students of all VARK preferences do not display the drawing effect which may reflect a nuance in adolescent cognition or the recent modification of high school instructional practices. The findings of this study may encourage high school educators to focus more on quality of content rather than medium of presentation to create memorable lessons. Further research may determine whether the results of this research are consistent across age groups and with other high school student demographics.

Introduction

For as long as humanity has existed, so has the practice of drawing. As early as 20,000 years ago, drawing served as a medium of emotional expression and detailed communication (Petherbridge, 2010), and is often regarded as a tool that bestows "skill and power, [...] improves judgment and taste, [...] cultivates habits of observation and accuracy, [...] and disciplines the mind like mathematics" (N. S., 1863). In addition to its aesthetic, emotive, and communicative abilities, drawing has also been utilized as a learning tool to aid in memory encoding processes (Wammes, Fernandes, & Meade, 2016). The consistent finding that drawn items are remembered better than written items, known as 'the drawing effect,' has influenced modern educational practices as educators work to make the content of their classes easier to encode and recall (Terada, 2019).

In recent years, education has also been revolutionized by the introduction of the VARK learning model by Neil Fleming of Lincoln University, which classifies learning into visual, aural, reading/writing, and kinesthetic categories, the first letters of which create the acronym 'VARK' (Fleming & Mills, 1992). As the drawing effect and VARK model have begun to inform modern educational strategies with the goal of encouraging information retention and recollection in students, it is critical to understand how the drawing effect and VARK preferences might relate to and support each other in order to maximize their respective advantages in the classroom.

The memorial benefits of drawing are widely understood in literature, as they draw upon many established principles of memory such as the 'picture superiority effect' and advantages of 'duration' and 'generation' (Paivio & Csapo, 1973; Slamecka & Graf, 1978; Cooper & Pantle, 1997). However, little is known about how high school-aged children exhibit the drawing effect, if at all. Additionally, it is not known how or whether VARK learning styles influence the manifestation of the drawing effect in high-school learners.

This study seeks to determine whether high school students exhibit the drawing effect and whether the drawing effect is displayed with more comparative intensity by one or more learning preferences of the VARK model. This

study may help educators better understand the processes of learning in high school students and thereby inform the creation of or modifications to high school educational programs and strategies.

Literature Review

The Picture Superiority Effect

The efficacy of pictures as an aid to memory is consistent in literature and underpinned by the well-supported understanding that *pictures* are better remembered than *words* (Paivio & Csapo, 1973). This 'picture superiority effect' was first named by Allan Paivio, researcher for the Department of Psychology at the University of Western Ontario, and Kalman Csapo, researcher for the London Psychiatric Hospital. Paivio and Csapo attribute "the usual superiority of pictures in free recall" to the 'dual-coding theory' (1973), which holds that pictures are more readily remembered because they can be encoded in both verbal and visual forms. Other research from Paivo supports this theory, finding that pictures of objects are significantly better recalled than their names (Paivio, Rogers & Smythe, 1968) and that pictures facilitate associative learning significantly better than nouns (Paivio & Yarmey, 1966), overall providing enduring evidence that "synergistic interactivity of verbal and nonverbal systems" creates significant memorial benefits (Paivio, 2014).

Experimentation with the Picture Superiority Effect

Literature has consistently identified and supported the picture superiority effect across various methodologies and paradigms since its identification in the early 1970s. Edward Rowe (1972), researcher for the Department of Psychology at Memorial University of Newfoundland, identified that "pictures [are] learned more rapidly and with fewer errors than words," and, while administering a free recall test, discovered that information learned via images is recalled more accurately than information learned via words, regardless of whether responses are verbal or nonverbal. A *Journal of Experimental Psychology* study by Joan Snodgrass and Peter McClure (1975) tested different methods of storage and retrieval for pictures and words, finding that pictures are recalled well under various memory storage instructions, such as verbalizing or imaging. Similarly, researchers Hikari Kinjo and Joan Snodgrass of New York University (2000) compared the priming of words and pictures in an implicit memory task, finding a consistent "robust picture superiority in recall" in picture exposure that is absent in word exposure. Finally, researcher William Hockley (2008) from Wilfrid Laurier University found that the "picture superiority effect extends to associative recognition" and recognized a greater encoding benefit for picture pairs compared to that of word pairs.

Memorial Advantages of Drawing

Given the many advantages of encoding information through images as opposed to words, it follows that creating drawings also improves retention and recollection. Besides incorporating memory-friendly pictures, drawing also aids memory through its basis in generation and duration. Research has emphasized the superiority of learning through internal generation, as internally generated stimulus is remembered better than externally presented stimulus (Slamecka & Graf, 1978); as learners must internally generate images to associate with presented information when drawing, it stands to reason that drawing strengthens encoding and recollection abilities. Further, the process of drawing an object requires more time and is more engaging than simply writing an object's name; since accuracy of memories correlates positively with time spent studying information, it follows that this time difference leads to memorial advantages (Cooper & Pantle 1997).

The Drawing Effect

Dr. Jeffrey Wammes, researcher for Yale University's Turk-Browne Lab, has extensively researched the positive effects of drawing on memory termed the 'drawing effect.' Wammes's research consistently suggests "a large and reliable advantage in memory performance for items that were previously drawn relative to those that were written," across various instructions, encoding strategies, and paradigms (Wammes et al., 2016). Wammes highlights that drawing "improves memory by encouraging a seamless integration of semantic, visual, and motor aspects" of encoding (Wammes et al., 2016), and by "promoting the integration of elaborative, pictorial, and motor codes" that facilitates the "creation of a context-rich representation" (Meade, Fernandes, & Wammes, 2018). Similar to Paivo's dual encoding theory, many advantages of drawing are due to its incorporation of multiple cognitive processes and sensory modalities including elaborative, motoric, and pictorial components that layer upon each other, making drawing a distinct and memorable encoding process (Wammes, Jonker, & Fernandes, 2019).

Picture Superiority and the Drawing Effect across Demographics

The presence of the picture superiority effect has been tested across three primary demographics - elementary school students, undergraduate and graduate university students (young adults), and older adults - with results supporting a trend of increased prominence of the picture superiority effect with age; literature indicates "an equivalent picture superiority effect for both young adults [mean age - 20.7 years] and older adults [mean age - 68.3 years] when pictures were compared to words," (Maisto & Queen, 1992), a result consistent with previous research (Craik & Simon, 1980; Keitz, 1976; Laurence, 1966). Similarly, the drawing effect significantly [enhances] memory performance in older adults; studies have found that older adults can remember an average of 2.513 times more drawn items than written items in free recall (Meade et al., 2018). The drawing effect is also consistently exhibited across the young adult demographic, who have exhibited an ability to freely recall an average of 1.9 times more drawn items than written items in previous research (Wammes et al., 2016).

Several studies have identified that elementary school age children may deviate from the established trend of picture superiority under certain conditions; when time allotted for encoding was decreased, the picture superiority effect "appeared only among 11- and 20-year-old groups, while a significant reverse of the picture superiority effect was detected in the youngest group," indicating that different levels of mental development might contribute differently to memory and encoding (Defeyter, Russo, & McPartlin, 2009). Similarly, although adults recall information presented as images better than information presented as words, "no difference is found across presentation modes for the fourth and sixth graders," suggesting that "cognitive structures of children do not utilize [imaginal or colored] stimulus information" to the same extent as adults (Borges & Stepnowsky, 1977). Together, this information indicates that "different memory processes [such as familiarity and recollection] contribute differently to the picture superiority effect at different stages of development," suggesting that the picture superiority effect and drawing effect may manifest at varying levels of intensity for different ages (Defeyter et al., 2009). This research with the picture superiority indicates that the drawing effect, which has not been tested in children or teens, may also exhibit itself differently across various ages. However, this notion lacks factual support as research regarding the drawing effect in children and adolescents is limited.

VARK Model of Learning Preferences

Literature from educational and psychological fields indicates that "learners of all ages have different yet consistent ways of responding in learning situations," possessing cognitive predispositions commonly known as 'learning preferences' (Fleming & Mills, 1992). Neil Fleming of Lincoln University developed the VARK Model in 1992 to encompass these learning preferences, which include four categories: visual, aural, reading/writing, and kinesthetic. The

VARK Model holds that learning occurs best when the mode of information presentation matches the preferred learning style of a student (Fleming, 2011).

The VARK learning model has been applied to education in multiple disciplines, such as computer science (Kalnishkan, 2005), to help educators improve their teaching and encourage students' learning. In congruence with VARK learning models, research has proven that viewing illustrations, listening to and speaking words, reading/writing words, and creating drawings can aid learning and lead to superior information retention, suggesting that each learning preference in the VARK model has potential to enhance memorial capabilities (Levie & Lentz, 1982; Fawcett, 2013; Forrin, MacLeod, & Ozubko, 2012; Wammes et al., 2016).

The Gap

Many existing studies address the memorial advantages of drawing across various methodologies and paradigms, creating an understanding of drawing's comparative superiority relative to words based on drawing's multiple levels of encoding and basis in images. However, the drawing effect has not been tested on subjects aged 16-17; little is known about its influence in the cognition of high school students. Moreover, it is unclear how learners of each VARK learning preference respond differently, if at all, to the utilization of drawing as an encoding tool or whether learners from a particular VARK style exhibit the drawing effect especially well. To address these gaps, this study will test high school students for the drawing effect, and each subject will subsequently be tested to determine their relative strength in each of the four VARK learning preference categories. Subjects' scores on recall tests will be analyzed against their VARK preferences to measure the presence or absence of the drawing effect in the high school demographic and how members of each VARK learning type may exhibit the drawing effect.

Hypothesis

Due to drawing's activation of motor, visual, and semantic aspects of memory that play into the strengths of multiple VARK learning preferences, it is hypothesized that high school students of all VARK learning types will exhibit the drawing effect and display results similar to those of 20-60 year old adults when similarly tested. The developmental differences suspected to affect the exhibition of the drawing effect in young children are predicted to be outgrown by high school students and thus have no influence on memory.

Method

Modified Experimentation

This study modified procedures for Experiment 1A outlined in "The drawing effect: Evidence for reliable and robust memory benefits in free recall," originally performed on 30 undergraduate students at the University of Waterloo by Jeffrey Wammes, Melissa Meade, and Myra Fernandes, researchers from the Department of Psychology at the University of Waterloo. The aim of Wammes's experiment was to determine whether "drawing would provide a benefit to later memory performance," and tested "recall of incidentally encoded words [either drawn or written …] after a brief retention interval," an intention that was preserved in spite of the various modifications.

Topical modifications to this original study included changing the tested demographic from undergraduates to high school students and changing the post-experiment questionnaire from one regarding a participant's memorial abilities to one identifying a participant's VARK learning subscores. These modifications allowed for a different demographic to be tested for the drawing effect, filling a gap in scientific literature and allowing students' recall scores to be analyzed against their VARK subscores to make possible identification of potential relationships between recall score and learning preferences.

Procedural modifications to the original study included utilizing different software for stimulus presentation and response recording in addition to reducing the number of presented stimuli with a corresponding reduction in time allowed for recall. The E-prime v2.0 software used in the Wammes (2016) study for the filler task and encoding task could not be accessed due to financial and copyright restrictions. Instead, Java 8.01 software was developed to create programs exactly mimicking the software described in the Wammes study (Wen 2020, "Recreated Encoding Task"; Wen 2020, "Recreated Filler Task"). Additionally, the number of stimuli presented to experimental subjects was reduced from 30 items to 14, and the recall period was reduced from 60 seconds to 28 seconds. This reduction in stimuli accounted for the finding that human capacity for memory develops markedly between ages 3-17, indicating that adolescents have a comparatively weaker memorial ability (Giedd, 2008); thus, the number of stimuli was decreased accordingly. The recall period was reduced to preserve the Wammes study's original proportion of two seconds provided per stimulus.

Lastly, analytical modifications to the original study included using a matched pairs t-test to test for a statistically significant difference between number of drawn words and written words recalled rather than the 2×2 mixed measures analysis of variance test (ANOVA) used in the Wammes study. The ANOVA test, which is used to test for statistically significant differences between the means of three or more independent groups, was not used since it was beyond the scope of this study, which only aimed to test for a significant mean difference between only two sets of paired data; this study did not seek to identify relationships between variables in the same way the Wammes (2016) study sought to find a correlation across multiple experiments.

Participants

Participants in this experiment were 30 high school juniors (15 female) from Lovejoy High School, who participated voluntarily. Participants ranged in age from 16-17 (Mean = 16.267), and as in the Wammes (2016) study had "normal or corrected-to-normal vision, and learned English before the age of seven."

Materials

Word List
The 80-word item words list (Appendix A) used in the Wammes (2016) study was used for this study. This list was originally generated by Wammes, Meade, and Fernandes (2016) from a 260-item list of verbal labels for images (Snodgrass & Vanderwart, 1980); the 80 words were selected based on how easily they could be represented with a drawing (i.e. 'apple' favored against 'clown') to reduce "the time it would take participants to create each of the drawing" and ensure that "every word could be drawn in the time provided, based on a pilot study, and no item required excessive visual detail to be discernible." The rationale used to select this word list applies to a high school demographic, so the same 80-item list was used in this study.

Filler Task
The continuous reaction time task used in the Wammes (2016) study was recreated in this study; this task was "created by making sound files representing low-, medium-, and high-pitched tones." This was accomplished using version 2.3.2 of Audacity® recording and editing software[1], "such that each sine wave tone was exactly 500 ms long, at frequencies of 350, 500, and 650 Hz, respectively." In many memory and encoding-related experiments, filler tasks serve to "prevent covert rehearsal" of encoded stimulus information (Groninger, 1966); as the filler task in Wammes

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[1] Audacity® software is copyright © 1999-2019 Audacity Team. Web site: https://audacityteam.org/. It is free software distributed under the terms of the GNU General Public License. The name Audacity® is a registered trademark of Dominic Mazzoni.

(2016) satisfies these requirements by engaging subjects with an auditory task sufficiently different from the semantic task of drawing/writing to prevent covert rehearsal, the Wammes (2016) filler task was found to be valid and thus replicated in this study.

Questionnaire

After the retrieval phase of this experiment, participants completed the online VARK questionnaire version 8.01[2] to identify their four numeric VARK subscores and submitted these results via a Google Form (Appendix B). The VARK questionnaire contained 16 questions describing various scenarios with four check-box answer choices, each describing a learning technique corresponding to one of the four VARK learning preferences. Students were informed to check the boxes that best reflected their preferences, with the option to skip questions if irrelevant or select multiple answers to reflect the full scope of their preferences. The questionnaire calculated each student's visual, aural, read/write, and kinesthetic VARK subscores on a scale from 0-16. The Wammes (2016) study used the Vividness of Visual Imagery Questionnaire (VVIQ), which determined participants' ability to draw and visualize images; this step was modified by replacing the VVIQ with the VARK questionnaire to determine each subject's VARK learning preferences. This modification provided data that the VVIQ did not provide, allowing student's VARK learning preferences to be identified and analyzed in relation to their recall scores. Otherwise, the VARK questionnaire was presented in the same manner and timing as the Wammes (2016) study, in keeping with the notion that questionnaires must be presented after experimentation to avoid predisposing subjects to certain behaviors that reflect their questionnaire results (Mutz, 2011).

Procedure

As in the Wammes (2016) study, "participants completed the experiment individually," and were not informed of the experiment's purpose. Stimulus presentation and response recording for both the encoding task and filler task were presented via a Fujitsu laptop with a 17-inch monitor and controlled using software developed by programmer Mark Wen[3]. As in the Wammes (2016) study, instructions for the experiment were both presented on the computer screen and read aloud by the experimenter. Participants were instructed to either 'draw' or 'write' presented words on the pad of paper (14cm x 21cm) provided; "a prompt of 'draw' meant the participant was to draw a picture illustrating the word on the screen and to continue adding detail until their allotted time was exhausted," and "a prompt of 'write' meant the participants were to clearly and carefully write out the word multiple times" (Wammes et al., 2016). Participant's responses to this instruction included block letters, shading, drawing multiple images, and writing with different scripts (Appendix F). As in the Wammes (2016) study, participants "were informed of time constraints for each item and that they would hear a tone to warn them that the next item would appear," and participants were not told that their memory would be later tested to "reduce the possibility that participants would develop a strategy of preferentially focusing on drawn items in anticipation of later testing."

[2] © Copyright Version 8.01 (2019) held by VARK Learn Limited, Christchurch, New Zealand.

[3] To obtain Wen's assistance, the researcher of this study contacted Lovejoy High School's AP Computer Science teacher, who connected her with Mark Wen, an accomplished Computer Science student at Lovejoy High School. The researcher provided Wen with a document outlining how the two software programs (filler task and encoding task) were to operate (Appendix D). After Wen coded the two programs, the researcher met up with Wen several times to discuss the abilities/limitations of Java software, troubleshoot, and test the programs to ensure they operated exactly as intended.

Encoding

After a brief practice with the software, participants began the experiment, without knowing they would later complete a memory test based on the provided stimuli. As in the Wammes (2016) study, "from the list of 80 words, [14][4] were randomly selected to be studied, a list unique for each participant," half of which were randomly assigned a 'draw' prompt and the other half assigned a 'write' prompt; this [14]-word set was then presented in a randomized order to randomly intermix prompts for drawing and writing. For each trial, "the prompt appeared in the centre of the screen for 750 ms, followed by a 500-ms fixation, after which the word to be encoded appeared for 750 ms. Participants then had 40s to perform the encoding task, either draw or write. A 500-ms tone alerted participants that the next item was forthcoming, after which they had 3s to flip [to the next paper] in preparation for the next prompt" (Wammes et al., 2016).

Retention

As in the Wammes (2016) study, after completing stimulus encoding, participants performed the filler task to prevent covert rehearsal (Groninger, 1966), in which participants classified 30 tones "as low, medium, or high, by pressing the 1, 2, or 3 key on a small response pad [...]. For each trial, the tone was played for 500 ms, after which participants had 1500ms to make their response, for a total of 2000 ms per trial. Thus the retention interval was one minute."

Retrieval

After completing the filler task, participants were prompted to "freely recall as many words as they could, in any order, either written or drawn, from earlier in the experiment" (Wammes et al., 2016). A maximum of 28 seconds was allotted for this portion of the experiment, which was spoken aloud by the participant and recorded digitally.
Questionnaire. Immediately after completing the experiment, participants completed the VARK questionnaire to identify their VARK subscores and submitted their results along with their age and gender via a Google Form (Appendix B).

Data Collection

Each participant's audio recordings were subsequently compared to their assigned list of drawn and written words to determine the quantity of drawn and written words recalled (Appendix D).
Data Analysis. A matched pairs t-test was used to test for statistical significance between drawn and written recall scores, using null hypothesis H_0: $\mu = 0$ against two alternative hypothesis H_1: $\mu \neq 0$ (testing for a positive or negative difference between drawn minus written recalls core) and H_1: $\mu > 0$ (testing for a positive difference in drawn minus written recall score). Scatterplots were used to test for correlation between VARK preference and recall score; participants' VARK scores were plotted against their drawn recall score in one graph and their written recall score in another for each VARK preference (Appendix F). The r values of each plot's slope, calculated using least-squares-regression trendlines, were used to test for statistically strong relationships between each preference and both recall scores.

Results

Difference Between Number of Recalled Drawn Words and Written Words

Overall, the majority of participants exhibited strengths across multiple VARK learning styles and succeeded in recalling both drawn and written words (*Table1*), with 29 participants recalling at least one drawn word and 26

[4] Number bracketed because this quantity is different from the number originally within the Wammes 2017 study's quoted material; it was changed from 30 to 14.

participants recalling at least one written word. Of the four VARK preferences, kinesthetic score was highest (10.367), followed by aural (8.033), then visual (6.667), then read/write (4.833).

Table 1. Each participant's Visual (V), Aural (A), Read/Write (R/W), and Kinesthetic (K) subscores and recall scores. Recall scores give the whole number of drawn and written words recalled. These numbers are obtained from participant responses (Appendix D).

Participant	VARK Subscores				Recall Score	
	V Score	A Score	R/W Score	K Score	Drawn	Written
1	5	5	2	10	5	2
2	6	6	3	8	3	1
3	7	7	3	13	2	2
4	2	9	1	6	2	4
5	6	14	3	8	3	4
6	0	6	0	10	3	3
7	12	13	9	16	2	2
8	7	9	1	9	2	0
9	6	4	4	9	2	0
10	2	13	8	8	3	4
11	4	5	6	14	1	0
12	11	10	7	11	3	3
13	7	5	3	8	3	3
14	7	2	12	10	3	3
15	8	8	11	10	5	4
16	9	9	4	13	3	2
17	4	2	0	11	3	0
18	6	13	4	11	4	3
19	10	13	3	15	5	1
20	7	10	7	10	2	2
21	4	13	4	13	1	4
22	11	9	3	8	3	2
23	3	2	2	10	0	4
24	1	8	2	5	1	2
25	5	3	9	4	2	1
26	4	10	4	14	3	2
27	12	9	10	11	3	2
28	11	10	9	14	4	5
29	10	1	6	10	2	3
30	13	13	5	12	1	1
Averages:	6.667	8.033	4.833	10.367	2.633	2.3

There was no statistical significance at **α**=0.05 in differences in the number of drawn and written words recalled. Although the average number of recalled drawn words (M=2.633) was greater than the average number of recalled written words (M=2.3), this difference was not statistically significant (*Table 2*).

Table 2. Mean differences (drawn minus written) for recalled words. These numbers are obtained from participant responses (Appendix D) and the list of differences between the number of drawn and written items.

	μ≠0	μ>0
T-Value	1.0685	1.0685
P-Value	0.2941	0.1471
Mean of Differences	0.3333	0.3333

Relationship between VARK Subscores and Recall Score

Table 3. Summary of correlative relationships between each VARK subscore and number of drawn words recalled/written words recalled. Correlation r values were calculated using least-squares-regression trendlines (Appendix G)

		Drawn	Written
Visual	Correlation r	0.228	-0.326
	Relationship	Very Weak	Weak
Aural	Correlation r	-0.349	0.182
	Relationship	Weak	Very Weak
Read/Write	Correlation r	0.484	0.228
	Relationship	Weak	Very Weak
Kinesthetic	Correlation r	-0.055	-0.663
	Relationship	None	Moderate

There was no strong correlation between any of variables (*Table 3*); all relationships were weak or very weak with two exceptions: the relationship between kinesthetic score and number of drawn items recalled was nonexistent with a correlation r < |0.1|, and the relationship between kinesthetic score and number of written items recalled was moderate with a correlation r > |0.6|.

Analysis

Wammes, Fernandes, and Meade, using the method described above, identified a "*significant recall advantage* [emphasis added] for words that were drawn during incidental encoding as compared to those that were written," with participants recalling nearly twice the number of drawn words compared to written words. The results of the Wammes study were inconsistent with the findings of this study, which identified *no significant advantage* for drawn words compared to written words. The results of this study signify a notable deviation from previous literature surrounding the drawing effect, which also largely supports the exhibition of the drawing effect in both younger and older adults. These results may indicate a nuance in the cognition of high school students not present after the age of 18 that affects motor, visual, and semantic aspects of memory, ultimately preventing the exhibition of the drawing effect. Literature

has identified adolescence as a critical period of maturation in neurobiological processes; this development is marked by an increase of activity in the frontal lobe and is paralleled by "increased abilities in abstract reasoning, attentional shifting, response inhibition and processing speed" (Yurgelun-Todd, 2007). This interval of cognitive growth may have a slight effect on memorial processes and stimuli encoding, but research supports that frontal lobe functionality is related more to emotional and behavioural regulation than encoding or retrieval (Halász, Toth, Kallo, Liposits, & Haller, 2006).

A more reasonable explanation for this phenomenon may lie in the recent modification of high school instructional practices. Contemporary high school education reforms have encouraged classrooms to implement a "rigorous standards-based system" with "relentless focus on student results," shifting focus away from lecture, practice, and review toward "cognitively complex tasks required by new standards" (Marzano, Carbaugh, & Toth, 2017). Additionally, contemporary educational pedagogy emphasizes discussion-based learning to promote "knowledge sharing and knowledge creation [...] as elements for improving the students' learning outcomes," with an ultimate goal of leading students toward "new knowledge creation [and] innovation in the future" (Sriratanaviriyakul & El-Den, 2019). Students educated by this new system, which prioritizes standards of inspiration, curiosity, and innovation over letter-grades and numerical benchmarks, may be more sensitive to the results of their learning rather than the process, indicating a shift of focus away from medium of learning and toward application of learning. As such, it stands to reason that these students make less distinction between modes of information reception, be it drawn, written, or otherwise, with increased focus on retention and application of knowledge.

Changes in instructional practices may also account for the lack of strong correlation between learning preferences and number of either drawn or written words remembered. Recent literature has reinvestigated the notion that "individuals learn better when they receive information in their preferred learning style" and suggested that it is a misconception, proposing instead that a student's learning preferences do not determine success or failure of stimulus encoding or classroom learning (Howard-Jones, 2014).

In addressing this hypothesis, researchers have identified that learning preferences do not determine a student's ability to learn from other styles of teaching, but merely indicate partialities or predilections. Studies with university students found that VARK results had no correlation with course outcomes when students were assigned study strategies designed to correlate with their VARK assessment (Husmann & O'Loughlin, 2018), and other research has also indicated that there is "no discernible [difference in student scores] attributable to learning style variation" (Curry, 1990). Studies which have suggested the opposite - that an increase in score will occur when students receive instructions that match their preferred learning style - were later questioned due to their "serious methodological issues" such as excluding outliers for unspecified reasons and not reporting all data (Pashler, McDaniel, Rohrer, & Bjork, 2008).

Overall, while there is enduring evidence supporting the existence of learning preferences in students and that students may receive information with more ease when it is presented in a preferred style, there is no evidence that learning is prevented or inhibited if information is not presented in a preferred style (Roediger & Karpicke, 2006); as such, educational pedagogy now operates under the idea that "there is no adequate evidence base to justify incorporating learning styles assessments into general educational practice" (Pashler et al., 2008). Many high school educators have accordingly decreased specific catering to each individual learning preference and instead focus on creating generally comprehensive, multimedia lessons (Marzano et al., 2017). This shift, along with a heightened emphasis on content and application of education rather than medium, may explain why high school students do not exhibit the drawing effect and display no correlative relationship between learning preferences and recall score.

Limitations

Due to the limited sample size of 30 participants, this research was unable to test for correlation using students' singular, most prominent VARK learning preference, but rather used each student's four VARK subscores. If this research had instead used one learning preference per student, 30 students of each learning preference would have been

tested for a difference in the average number of drawn versus written words recalled using a mixed ANOVA test or chi-square hypothesis test. This method of analysis might have revealed an unanticipated relationship between learning preferences and recall score from the one discovered in this study.

Additionally, the demographic of Lovejoy High School may not be representative of all high school students. As comparatively wealthy and well-educated students, most of whom have attended public school for at least 10 years, the learning habits and educational preferences of participants in this study may differ from students elsewhere.

Implications

There still exists a significant gap within literature regarding the cognitive processes and preferences of high school students; university students and young adults remain the most commonly researched demographic. A more nuanced understanding of adolescent cognition, especially regarding memorial processes and learning behaviors, may aid in the explanation and prediction of various behaviors which may instigate further reform in educational pedagogy. Further research regarding the manifestation of the drawing effect in adolescents may determine whether the results of this research are consistent across age groups and with other high school student demographics.

The results from this research may be useful in further informing educational pedagogy to better address the strengths and predilections of high school learners. According to an article published in Forbes Magazine, many high school educators still "believe in ideas and methods that have little or no evidence behind them," such as an "overestimation in the importance of learning styles" and preferences in determining a student's ability to learn successfully (Wexler, 2018). The findings of this study promote a movement away from this misconception and encourage high school educators to decrease focus on the medium of their lessons, as such a focus does not largely affect a student's ability to recall material. Instead, focus on quality of content rather than mode of presentation may better enable teachers to create memorable lessons.

Acknowledgements

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