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Citation: Chan, David, Rajsic, Jason and Pratt, Jay (2017) Go-getters and procrastinators: Investigating individual differences in visual cognition across university semesters. Vision Research, 141. pp. 317-324. ISSN 0042-6989

Published by: Elsevier

URL: http://dx.doi.org/10.1016/j.visres.2016.09.007 <http://dx.doi.org/10.1016/j.visres.2016.09.007>

Go-Getters and Procrastinators: Investigating Individual Differences in Visual Cognition across University Semesters

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Accepted: September 9, 2016

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Abstract

University-based psychological research typically relies on the participation of undergraduate students for data collection. Using this relatively constrained sample brings with it several possible issues, including the self-scheduling done by the participants. Research on performance between students who sign up early versus late in the semester is inconsistent, with research reporting either benefits for early semester participants (Richert & Ward, 1976) or no differences between the two groups (Wang & Jentsch, 1998). Anecdotally, it seems that the former holds true, as many researchers tend to avoid collecting data late in the semester, opting for more motivated earlier participants in the next semester. The purpose of our study was to examine for the effect of time of semester across a well-known set of visual cognition tasks. To do so, participants completed canonical versions of a rapid serial visual presentation (RSVP) task, a flanker task, an additional singleton paradigm task, a multiple object tracking (MOT) task and a visual working memory (VWM) task. Crucially, we correlated task performance with time of semester students chose to participate. Our results demonstrate that there were no significant differences in any of the tasks across semester timing. Furthermore, our findings support the validity of cognitive research relying on the system of recruiting undergraduate students from volunteer pools where students can self-select the time of the semester they undertake the experiments.

The study of visual cognitive processes, such as what we now term visual attention and visual working memory, is one of the historical cornerstones of experimental psychology. Indeed, among the earliest experiments conducted in psychology concerned visual cognitive performance and its limitations (e.g., Helmholtz, 1896; Wundt, 1907). As psychology labs were, and still are, typically located at universities, it is not surprising that, since its earliest days, experimental psychological research has relied heavily on samples of university students. The benefits of this sample are straightforward: data can be collected with minimal time and expense. This practice, however, has not escaped notice, with researchers raising concerns about the validity and generalizability of college and university students to the general population (Jung, 1969). Furthermore, voluntary research participation among students enrolled in courses suffers from an inherent sampling confound: self-selection. Specifically, participants typically choose when to participate in studies, and participants that choose to sign up early in the semester ("go-getters") may have different characteristics than participants that chose to sign up at the end of a semester ("procrastinators"). In other words, experiments whose data have been collected at different periods of a semester may suffer confounds if individual differences in visual cognitive performance covary with individual differences in participation preferences.

Perhaps surprisingly, scant research has been conducted to address the possibility of semester effects in experimental psychology tasks. The earliest explicit comparison of performance between early- and late-sign up participants that the authors are aware of is that of Underwood, Schwenn, and Keppel (1964), who examined paired-associate learning. Their analyses revealed no differences in performance by participation time. Subsequent studies have often shown differences in self-reported measures of personality variables (e.g., Evans & Donnerstein, 1974; Holden & Reddon, 1987; Hom, 1987; Aviv, Zelenski, Rallo, & Larsen, 2002;

Zelenski, Rusting & Larsen, 2003), but differences in performance are equivocal. Null differences have been reported for cued-recall (Wang & Jentsch, 1998), signal detection, performance-based vigilance tasks (Tomporowski, Simpson & Hagar, 1993), and text comprehension (Langston, Ohnesorge, Kruley, & Haase, 1994). However, differences in performance have been reported for visual search (Richert & Ward, 1976), symbol substitution and serial learning (Richter, Wilson, Milner, & Senter, 1981), and, recently, sustained attention (Nicholls, Loveless, Thomas, Loetscher, & Churches, 2015) with the general trend that early semester participants demonstrate overall better performance than late semester participants.

Very recently, however, research has shown that there may be little to no effect of semester timing on a variety of tasks. Robison & Unworth (2016) conducted a large, multi-university study across a variety of measurements. Participants completed tasks to measure working memory capacity (operation span, symmetry span and reading span tasks), long term memory (delayed free recall, picture-source recognition and cued recall tasks), attentional control (antisaccade, psychomotor vigilance task, and arrow flankers), fluid intelligence (Raven advanced progressive matrices, verbal analogies and number series tasks), and crystallized intelligence (synonym and antonym vocabulary and general knowledge tasks). The general finding was that there were no individual differences that covary with the time at which participants chose to participate.

Our concern in the present study was the area of visual cognition, and visual attention, an area that has seen rapid growth over the last three decades (see Carrasco, 2011). Individual differences are known to exist in visual-cognitive ability (e.g., Green & Bavelier, 2003; Fukuda & Vogel, 2009), and there is a strong possibility that early and late volunteers may differ in their ability to complete tasks involving visual cognition. However, in light of recent research

(Robison & Unsworth, 2016), these differences may not be reflected in self-selected participation times. Assessing the extent and character of these differences is critical for ensuring that data in such experiments are reliable, especially if experimental and control conditions are run between-subjects as separate experiments. Furthermore, our present study aims to provide insight as to how individual differences may play a role specifically in visual attentional and cognitive tasks.

In order to evaluate whether early and late volunteers differ in their visual cognitive abilities, we administered a visual cognitive battery designed to test five components of visual cognition: executive control, temporal selectivity, visual working memory capacity, resistance to distraction, and attentional capacity. These abilities were operationalized using five tasks: a Flanker Task, a Rapid Serial Visual Presentation (RSVP) task to measure the attentional blink, the one-shot change detection task, an additional singleton visual search task, and a multiple object tracking task. In our first experiment, this battery was run at two time points within a single semester of an introductory Psychology course; the first three weeks and the last three weeks. In our experimental design, there were three possible outcomes for each task we have measured. Either participants who sign up earlier will demonstrate superior performance, equal performance or worse performance on these visual cognitive tasks. Based on the current literature, it seemed that the third option was the least likely, with research supporting the idea that early semester participants perform better (e.g. Richert & Ward, 1976; Nicholls et al., 2015), or that no differences exist between the two (e.g. Tomporowski et al., 1993; Wang & Jentsch, 1998). Moreover, anecdotal evidence also supports the first alternative; researchers at experimental psychology conferences are frequently concerned with their end of semester data. Concerns about early semester participants, however, are virtually unheard of. The question addressed by this study is exactly this; is there any empirical evidence to support this anecdotal evidence?

Experiment 1

Methods

Participants and Apparatus: Fifty five students, (16 males, 39 females, mean age = 18.88) enrolled in the undergraduate introduction to psychology course at the University of Toronto participated as subjects. Participants were informed of experimental participation on the first week of class. Each participant was given the opportunity to participate in two 1-hour experiments to receive credit up to a maximum of 1% of their total course grade. None of the participation was for bonus marks or for paid participation. Participants were able to sign up for this study on the first three and last three weeks of the participation pool (last three weeks of January and last two weeks of March/first week of April respectively). Twenty five students signed up in the early semester condition, and thirty signed up in the late semester condition. Our intention was to collect as many participants as possible during the appropriate weeks. Critically, no participants were recruited for our study, and participants were not aware that this study only accepted sign-ups during the critical week; from the participant's perspective, our study was simply one of several Psychology studies available to participate in at whatever time they chose to participate in a Psychology study. All participants reported normal or corrected-to-normal vision and none were aware of the hypothesis tested. Testing was conducted on a computer with a CRT monitor operating at a refresh rate of 85 Hz. A chin and head rest maintained viewing distance at 54 cm. Responses were collected on a standard keyboard. All stimuli were presented on a grey background.

Flanker Task: A Flanker task was chosen as one of the tasks in our attentional battery as a tool to assess the participants' ability to suppress responses that were invalid in a particular context. First used by Eriksen & Eriksen (1974), years of research suggests that the flanker task assesses executive control (Kopp, Rist & Mattler, 1996; Callejas, Lupianez, Funes & Tudela, 2005), and participants' ability to inhibit particular responses that may change with context (Eriksen, 1995). Our flanker task consisted of firstly a presentation of a white fixation cross for 1000ms. Next, a flanker display was presented, with a central distractor (a white "N", "F" or "X", approximately 1° x 1°, 25 trials for each distractor type), accompanied by a target letter in one of 6 possible target locations, all 8° from the distractor, forming a circle around the distractor. The target letter was either a white "N" or "X" (also 1° x 1°), with the remaining 5 locations occupied by a small white dot placeholder. The target display remained on the screen for 150ms, at which time participants were asked to indicate the identity of the target by pressing either "N" or "X".

Rapid Serial Visual Presentation (RSVP) Task: The use of a RSVP task to demonstrate the attentional blink has been well documented (Reeves & Sperling, 1986; Broadbent & Broadbent, 1987; Kanwisher, 1987; Kanwisher & Potter, 1989; Raymond, Shapiro & Arnell, 1992). A typical RSVP task (as used by Raymond & colleagues, 1992) presents participants with a stream of centrally fixated letters (approximately 1.5° x 1.5° each) in rapid succession. Participants are instructed to both indicate the target white letter (T1) in a stream of black letters, while also determining the presence of a second target (T2). What is commonly reported is that processing of the first target inhibits processing of the second target if it appears within 180-270ms after T1. This performance decrement is described as interference from the first target, creating a temporary suppression of attentional mechanisms, creating an attentional "blink". This result has been replicated across many different experiments (Raymond, Shapiro, Arnell, 1995; Di Lollo, Kawahara, Ghorashi, Enns, 2005), and has been generally assumed to be an outcome of the capacity-limit of temporal attentional (for review, see Dux & Marois, 2007). In our RSVP task, we presented participants with a white fixation cross for 1000ms. Following the fixation cross, participants were presented with 12 letters, each presented for 25ms with an inter-stimulus interval of 75ms between each letter presentation. In each trial, a target letter (T1) would appear (as white), with the possibility of the presentation of the letter "X" (T2) in the letter string. Participants were instructed to indicate the target white letter, as well as the presence or absence of the letter "X". The location of T2 in the stream of letters could either be 0 (T2 was not present; 40 trials), 3 (3 letters after the presentation of T1; 20 trials), or 6 (6 letters after the presentation of T1; 20 trials). T1 was reported by entering in the letter's identity on the keyboard and pressing the "Enter key". T2 presence or absence was reported subsequently by pressing the "X" key to denote the presence of an X in the preceding RSVP, or by pressing the "N" key to signal the absence of an X. (See Figure 2)

Multiple Object Tracking: In order to measure sustained attention, we opted to use a multiple object tracking (MOT) task. The MOT task provides an estimate of divided attention and individual tracking capacity (Scholl & Pylyshyn, 1999; Drew & Vogel, 2008). In our study, participants were presented with a display of 8 static blue circles, subtending approximately 0.4° in diameter, on a black display. Following a delay of 1 second, two (20 trials) or four (20 trials) of the dots would turn green. After 200ms, the green dots would turn back blue, and each dot would begin to move in a pseudorandom fashion with a speed of 18°/s within a bounded region subtending 24° x 24°. After a movement time of 8s, the dots would stop moving, and one would turn white. Participants were then asked to indicate whether this white dot was one of the originals they were asked to track. Participants responded in the affirmative using the “Z” key, or in the negative using the “M” key. (See Figure 3)

Additional Singleton Task: In order to test distractibility, we used an additional singleton paradigm (Theeuwes, 1991; 1992; 1994). In our task, participants completed 40 trials in which each trial started with a white fixation cross in the middle of the screen for 1000ms. Following the fixation cross, an array of 6 stimuli, approximately 3° in diameter, appeared in a ring formation around the location of the fixation cross, with each stimulus positioned 6.4° from fixation. In half of the trials, one of the stimuli would be colored (either green, red, blue, or yellow), while the rest of the distractors and target would be white. One stimulus, the target, was a square shape with a small gap in its left or right side (0.36°), whereas the distractor stimuli were circular shapes with gaps of the same size. On the other half of the trials, randomly intermixed, the target and distractors were all colored in white. This array was presented for until a response was given. Participants were instructed to indicate the location of the gap on the square (either left or right) while ignoring all other distractors. (See Figure 4)

Visual Working Memory (VWM) Task: Lastly, we used a standard visual working memory task to probe memory capacity as well as investigate correlations between the various tasks (Luck & Vogel, 1997). In our VWM task, participants were shown a white fixation cross in the middle of the screen for 1000ms. Following the fixation cross, an array of differently colored squares (1° each in diameter) were presented in a random array consisting of 4, 8 or 12 items for 100ms. After an SOA of 900ms, a second array consisting of the same number of objects was displayed in the same spatial configuration. This array remained on the screen for 3000ms or until response. In 50% of the arrays (36 trials), one object changed colors, while in the other 50% (36 trials), all colors remained the same. (See Figure 5). Participants were instructed to indicate whether the arrays are the same or different. Colors were sampled from a set of distinct colors (red, green, yellow, light blue, purple, pink, brown, white, and black), with replacement after the set had been exhausted when necessary (i.e, at Set Size 12).

Results

Flanker Task: Participants with errors greater than 2 standard deviations from the mean were excluded in the data analysis (1 participant from the early semester group). Overall accuracy scores were compared using an independent sample t-test, resulting in no significant differences between early and late semester participants, $t(53) = 0.112$, $p = 0.911$. Reaction times (RTs) were analysed using a mixed-model analysis of variance (ANOVA) with within factors as flanker type (congruent, incongruent or neutral), and a between factors of semester (early or late) (see Figure 6). There was a main effect of flanker type, $F(1,52) = 4.075$, $p = .049$, with congruent flankers producing the fastest RTs, and incongruent flankers producing the slowest RTs. More importantly, there was no main effect of semester timing, $F(1,52) = 0.350$, $p = .789$. Furthermore, there were no significant interactions between any of the flanker levels and semester effects, $F(1,52) = 0.670$, $p = .417$, cohen's $d = 0.22613$; $F(1,52) = 0.116$, $p = .735$, cohen's $d = 0.0941$; $F(1,52) = 0.805$, $p = .374$, cohen's $d = 0.248$; congruent, neutral and incongruent respectively.

RSVP Task: Accuracy scores were analysed using a repeated-measures analysis of variance (ANOVA) with within factors as T2 lag location (Lag 0, Lag 3 or Lag 6), and between factors as semester timing (early and late) (see Figure 7). When analysing the data in which T1 was correctly reported, there was a main effect of T2 lag, $t(1,53) = 8.116$, $p = .0001$, with detection of T2 at Lag 6 producing higher accuracy scores than at Lag 3. More importantly, there was no significant interaction between T2 lag effect and semester timing, $F(1,52) = 0.023$, $p = .881$, cohen's $d = 0.042$; $F(1,52) = 0.072$, $p = .789$, cohen's $d = 0.074$; $F(1,52) = 1.185$, $p = .281$, cohen's $d = 0.297$; Lag 0, Lag 3 and Lag 6 respectively. Furthermore, there was no significant difference in T1 detection between early and late semester participants, $F(1,52) = 1.045$, $p = .311$, cohen's $d = 0.278$.

Multiple Object Tracking: Participants with accuracy scores 2 standard deviations away from the mean were excluded from analysis (1 participant in the late semester group). Accuracy scores were analyses using a repeated-measures analysis of variance (ANOVA) with number of objects (2 or 4 objects) as within factors and semester timing (early and late) as between factors (see Figure 8). A main effect of number of objects was found, $F(1,52) = 43.051$, $p = .0001$, with tracking 2 objects producing higher accuracy scores than tracking 4 objects. More importantly, there was no main effect of semester timing, $F(1,53) = 1.618$, $p = .209$, and no significant interactions were found between early and late semester for both 2 and 4 object conditions respectively, $F(1,52) = 0.878$, $p = .353$, cohen's $d = 0.253$; $F(1,52) = 1.751$, $p =.191$, cohen's $d = 0.366$.

Additional Singleton Paradigm: Accuracy scores were analysed using an independent sample t-test, and found that there were no significant differences between accuracy scores across early and late semester participants when the singleton was present and not present, $t(1,53) = 0.359$, $p = .721$; t(1,53) = 0.075, $p = .967$ respectively. RTs were analysed using a mixed-model analysis of variance (ANOVA) (see Figure 9), and a main effect of singleton was found, $F(1,52) = 44.658$, $p = .0001$, with reaction times being slower when the singleton was present. However, more importantly, there was no main effect of semester timing, $F(1,52) = 0.008$, $p = .929$, and no significant interactions between singleton present/not present and semester timing respectively, *F*(1,52) = 0.064, *p* = .802, cohen's *d* = 0.099; *F*(1,52) = 0.017, *p* = .897, cohen's *d* = 0.011.

Visual Working Memory: Participants with accuracy scores greater than 2 standard deviations from the mean were excluded, which resulted in 7 participants (~10%) being excluded from analysis (3 from early semester and 4 from late semester). Memory capacity (*k*) was calculated for each participant using Pashler's method for whole-display change detection (see Rouder, Morey, Morey, & Cowan, 2011). *k* scores were analysed using a mixed-model ANOVA with set size (4, 8, or 12 objects) as a within subjects variable and semester timing (early or late) as a between subjects variable (see Figure 10). There was a main effect of set size, *F*(1,46) = 31.293, *p* = .0001, with the highest *k* scores for set size 4, declining with increasing set size. Most importantly, there were no main effects of semester timing (although it did show a trend towards significance), *F*(1,46) = 3.448, *p* = .181, and no significant differences between early and late semester participants across any of the three set sizes (4,8 & 12), *F*(1,46) = 0.203, cohen's *d* = 0.477, *p* = 0.654; *F*(1,46) = 0.042, *p* = 0.839, cohen's *d* = 0.348; *F*(1,46) = 2.018, *p* = 0.117, cohen's *d* = 0.659.

Discussion

Through these five visual cognitive tasks, we were able to demonstrate that there were no semester effects on any of these tasks, suggesting that participants who voluntarily sign up earlier in the semester perform the same as their end of semester counterparts. To further parse out the effect of semester timing on these visual cognitive tasks, we conducted a second experiment that divided the semester into three equal parts in order to see whether a parsing out the semester even further would yield any individual differences.

Experiment 2

Fifty five students, (16 males, 39 females, mean age = 18.88) enrolled in the undergraduate introduction to psychology course at the University of Toronto participated as subjects. Participants were informed of experimental participation on the first week of class. Each participant was given the opportunity to participate in two 1-hour experiments to receive credit up to a maximum of 1% of their total course grade. None of the participation was for bonus marks or for paid participation. Participants were able to sign up for this study throughout the whole semester. 15 students signed up for the early semester (the first four weeks), 18 signed up for the middle of the semester (the middle four weeks), and 16 signed up for the end of the semester (the last four weeks). Our intention was to collect as many participants as possible during the appropriate weeks. All participants reported normal or corrected-to-normal vision and none were aware of the hypothesis tested. All testing was done on the same equipment as Experiment 1, and the same tasks were completed as Experiment 1. All participants were naïve to the study and had not completed Experiment 1.

Results

Flanker Task: Overall accuracy scores were compared using a one-way ANOVA, resulting in no significant differences across all three semester times, $F(2,46) = 0.331$, $p = 0.720$. Reaction times (RTs) were analysed using a mixed-model analysis of variance (ANOVA) with within factors as flanker type (congruent, incongruent or neutral), and a between factors of semester (early, middle or late) (see Figure 11). There was a main effect of flanker type, $F(2,46) = 3.503$, $p = 0.039$, with congruent flankers producing the fastest RTs, and incongruent flankers producing the slowest RTs. More importantly, there was no main effect of semester timing, $F(2,46) = 0.0.431$, $p = .653$.

Furthermore, there were no significant three-way interaction between flanker type and semester timing, $F(2,46) = 0.577$, $p = .566$, cohen's $d = 0.018$.

RSVP Task: Participants with errors greater than 2 standard deviations from the mean were excluded in the data analysis (3 participants in the early semester, 2 in the middle of semester and 2 in the late semester). Accuracy scores were analysed using a repeated-measures analysis of variance (ANOVA) with within factors as T2 lag location (Lag 0, Lag 3 or Lag 6), and between factors as semester timing (early, middle and late) (see Figure 12). When analysing the data in which T1 was correctly reported, there was a main effect of T2 lag, $F(2,39) = 46.306$, $p = .0001$, with detection of T2 at Lag 6 producing higher accuracy scores than at Lag 3. More importantly, there was no significant interaction between T2 lag effect and semester timing, $F(2,39) = 0.057$, $p = .945$, cohen's $d = 0.003$; . Furthermore, there was no significant difference in T1 detection between early and late semester participants, $F(2,39) = 0.778$, $p = .466$, cohen's $d = 0.037$.

Multiple Object Tracking: Accuracy scores were analyses using a repeated-measures analysis of variance (ANOVA) with number of objects (2 or 4 objects) as within factors and semester timing (early, middle and late) as between factors (see Figure 13). A main effect of number of objects was found, $F(1,46) = 28.145$, $p = .0001$, with tracking 2 objects producing higher accuracy scores than tracking 4 objects. More importantly, there was no main effect of semester timing, $F(1,46) = 0.613$, $p = .0.546$, and no significant interactions were found between semester timing and number of objects, $F(2,46) = 2.137$, $p = .130$, cohen's $d = 0.085$.

Additional Singleton Paradigm: Participants with errors greater than 2 standard deviations from the mean were excluded in the data analysis (1 participant in each semester group).Accuracy scores were analysed using a one-way ANOVA, and found that there were no significant differences between accuracy scores across the different semester timings, $F(2,45) = 0.269$, $p = 0.766$. RTs were analysed using a mixed-model analysis of variance (ANOVA) (see Figure 14), and a main effect of singleton was found, $F(1,43) = 29.499$, $p = .0001$, with reaction times being slower when the singleton was present. However, more importantly, there was no main effect of semester timing, $F(1,43) = 0.976$, $p = 0.385$, and no significant interactions between singleton RTs and semester timing, $F(2,43) = 0.430$, $p = 0.653$, cohen's $d = 0.020$.

Visual Working Memory: Memory capacity (*k*) was calculated for each participant using Pashler's method for whole-display change detection (see Rouder et al., 2011). *k* scores were analysed using a mixed-model ANOVA with set size (4, 8, or 12 objects) as a within subjects variable and semester timing (early, middle or late) as a between subjects variable (see Figure 15). There was a main effect of set size, $F(1,48) = 215.113$, $p = .0001$, with the highest accuracy scores for set size 4, declining with increasing set size. Most importantly, there were no main effects of semester timing , $F(2,46) = 1.631$, $p = .207$ cohen's $d = 0.066$, and no significant interaction between set size and semester timing, $F(4,46) = 0.652$, $p = 0.627$, cohen's $d = 0.028$.

General Discussion

The goal of our study was to investigate whether data collected at different times of the semester would influence performance on a wide range of visual cognitive tasks. Our main, and very consistent, finding was that no differences existed between early and late semester participants across the five visual cognitive tasks used in the study. Quite frankly, given the demanding nature of these tasks, we were somewhat surprised at the clear lack of differences. Although all statistical comparisons were null, in a few cases, we observed small to moderate effect sizes. However, every one of these comparisons showed late participants outperforming early participants. The implications of these findings are important to visual cognition researchers; the self-selection of participation timing does not affect performance on widely used visual cognition tasks. Although research has demonstrated that there may be personality differences for participants who choose to sign up earlier in the semester as opposed to later (Evans & Donnerstein, 1974; Holden & Reddon, 1987; Hom, 1987; Aviv, Zelenski, Rallo, & Larsen, 2002; Zelenski, Rusting & Larsen, 2003; Witt, Donnellan & Orlando, 2011; Grimm, Markman & Maddox, 2012), these personality differences do not translate into performance differences on these visual cognition tasks.

Though we were unable to find any differences on these tasks, there still may be other performance differences between early and late semester participants. Prior research has shown that early semester participants tend to be more internally motivated (Hom, 1987), and that there may be a correlation between grade point average (GPA) and semester timing (Bender, 2007). Therefore, it may be the case that our tests were not sensitive enough to capture small changes in ability due to motivation. The recent demonstration of differences in sustained attention by Nicholls et al. (2015) is relevant to this issue, as they found differences between individuals who sign up early and late for studies are detectable in laboratory tasks. Importantly, such sustained attention tasks likely tax motivational differences in addition to purely cognitive differences. In this light, our results suggest that differences between early and late signup populations are not a function of variability in cognitive ability, as individual differences in motivation are expected to contribute little to performance in the tasks we have used (Robison & Unsworth, 2016). As such, the present results indicate that researchers measuring visual cognitive ability need not worry about the timing of their experiments during university semesters.

Despite research showing some effects of semester timing on a variety of tasks, our results corroborate the findings of Robison & Unsworth (2016). Our results show that semester timing play little to no role in influencing performance on these visual cognitive tasks. More importantly, our research extends the literature by demonstrating that tasks that measure attentional capacity, executive control and resistance to distraction are not influenced by semester timing.

In conclusion, this research supports the validity of cognitive research relying on the system of recruiting undergraduate students from volunteer pools where students can self-select the time of the semester they undertake the experiments. Although higher order tasks and personality differences may exist between students who select to volunteer early vs late in the semester, these differences are not robust enough to bias performance on visual cognitive tasks. Therefore, this study provides confidence, at least on a behavioural level, that students sampled throughout the semester are statistically equivalent.

References

Aviv, A. L., Zelenski, J. M., Rallo, L., & Larsen, R. J. (2002). Who comes when: Personality differences in early and later participation in a university subject pool. *Personality and Individual Differences*, *33*(3), 487-496.

Baddeley, A., Della Sala, S., Robbins, T. W., & Baddeley, A. (1996). Working memory and executive control [and Discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *351*(1346), 1397-1404.

Broadbent, D. E., & Broadbent, M. H. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & psychophysics*, *42*(2), 105-113.

Callejas, A., Lupianez, J., Funes, M. J., & Tudela, P. (2005). Modulations among the alerting, orienting and executive control networks. *Experimental Brain Research*, *167*(1), 27-37.

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision research*, *51*(13), 1484-1525.

Di Lollo, V., Kawahara, J. I., Ghorashi, S. S., & Enns, J. T. (2005). The attentional blink: resource depletion or temporary loss of control?. *Psychological research*, *69*(3), 191-200.

Drew, T., & Vogel, E. K. (2008). Neural measures of individual differences in selecting and tracking multiple moving objects. *The Journal of Neuroscience*, *28*(16), 4183-4191.

Dux, P. E., & Marois, R. (2009). The attentional blink: A review of data and theory. *Attention, Perception, & Psychophysics*, *71*(8), 1683-1700.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current directions in psychological science*, *11*(1), 19-23.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & psychophysics*, *16*(1), 143-149.

Eriksen, C. W. (1995). The flankers task and response competition: A useful tool for investigating a variety of cognitive problems. *Visual Cognition*, *2*(2-3), 101-118.

Evans, R., & Donnerstein, E. (1974). Some implications for psychological research of early versus late term participation by college subjects. *Journal of Research in Personality*, *8*(1), 102-109.

Fry, A. F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological science*, *7*(4), 237-241.

Fukuda, K., & Vogel, E. K. (2009). Human variation in overriding attentional capture. *The Journal of Neuroscience, 29*(27), 8726-8733.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, *423*(6939), 534-537.

Grimm, L.R., Markman, A.B., & Maddox, W.T. (2012). End-of-semester syndrome: How situational regulatory fit affects test performance over an academic semester. *Basic Applied Social Psychology, 34(4)*, 376-385.

Holden, R. R., & Reddon, J. R. (1987). Temporal personality variations among participants from a university subject pool. *Psychological Reports*, *60*(3c), 1247-1254.

Helmholtz, H. V. (1896). Vorträge und reden. *Braunschweig: Vieweg*.

Hom, H. L. (1987). A Methodological Note Time of Participation Effects on Intrinsic Motivation. *Personality and Social Psychology Bulletin*, *13*(2), 210-215.

Jung, J. (1969). Current practices and problems in the use of college students for psychological research. *Canadian Psychologist/Psychologie canadienne*, *10*(3), 280.

Kanwisher, N. G. (1987). Repetition blindness: Type recognition without token individuation. *Cognition*, *27*(2), 117-143.

Kanwisher, N., & Potter, M. C. (1989). Repetition blindness: The effects of stimulus modality and spatial displacement. *Memory & Cognition*, *17*(2), 117-124.

Klein, R. M., Schmidt, W. C., & Müller, H. J. (1998). Disinhibition of return: unnecessary and unlikely. *Perception & Psychophysics*, *60*(5), 862-872.

Kopp, B., Mattler, U., Goertz, R., & Rist, F. (1996). N2, P3 and the lateralized readiness potential in a nogo task involving selective response priming. *Electroencephalography and clinical neurophysiology*, *99*(1), 19-27.

Langston, W., Ohnesorge, C., Kruley, P., & Haase, S. J. (1994). Changes in subject performance during the semester: An empirical investigation. *Psychonomic bulletin & review*, *1*(2), 258-263.

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*(6657), 279-281.

Nicholls, M. E., Loveless, K. M., Thomas, N. A., Loetscher, T., & Churches, O. (2015). Some participants may be better than others: Sustained attention and motivation are higher early in semester. *The Quarterly Journal of Experimental Psychology*, *68*(1), 10-18.

Pylyshyn, Z. (1989). The role of location indexes in spatial perception: A sketch of the FINST spatial-index model. *Cognition, 32*(1), 65-97.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink?. *Journal of Experimental Psychology: Human Perception and Performance, 18*(3), 849.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1995). Similarity determines the attentional blink. *Journal of Experimental psychology: Human perception and performance*, *21*(3), 653.

Reeves, A., & Sperling, G. (1986). Attention gating in short-term visual memory. *Psychological review*, *93*(2), 180.

Richert, A. J., & Ward, E. F. (1976). Experimental performance and self-evaluation of subjects sampled early, middle, and late in an academic term: Sex and task. *Psychological Reports*, *39*(1), 135-142.

Richter, D. O., Wilson, S. D., Milner, M., & Senter, R. J. (1981). Some differences among students volunteering as research subjects. *Bulletin of the Psychonomic Society*, *17*(6), 261-263.

Robison, M. K., & Unsworth, N. (2016). Individual differences in working memory capacity and resistance to belief bias in syllogistic reasoning. *The Quarterly Journal of Experimental Psychology*, (just-accepted), 1-36.

Rouder, J. N., Morey, R. D., Morey, C. C., & Cowan, N. (2011). How to measure working memory capacity in the change detection paradigm. *Psychonomic Bulletin & Review*, *18*(2), 324-330.

Scholl, B. J., & Pylyshyn, Z. W. (1999). Tracking multiple items through occlusion: Clues to visual objecthood. *Cognitive psychology*, *38*(2), 259-290.

Siebler, J. E. (1999). What makes a subject pool (un)ethical? In Chastain, G. D. (Ed.), *Protecting human subjects: Departmental subject pools and institutional review boards* (43-64). Washington, DC: American Psychological Association, x, 228

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & psychophysics*, *49*(1), 83-90.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, *51*(6), 599-606.

Theeuwes, J. (1994). Endogenous and exogenous control of visual selection. *Perception-London*, *23*(4), 429-440.

Tomporowski, P. D., Simpson, R. G., & Hager, L. (1993). Method of recruiting subjects and performance on cognitive tests. *The American journal of psychology*, 499-521.

Underwood, B. J., Schwenn, E., & Keppel, G. (1964). Verbal learning as related to point of time in the school term. *Journal of Verbal Learning and Verbal Behavior*, *3*(3), 222-225.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: active maintenance in primary memory and controlled search from secondary memory. *Psychological review*, *114*(1), 104.

Wang, A. Y., & Jentsch, F. G. (1998). Point-of-time effects across the semester: Is there a sampling bias?. *The Journal of psychology*, *132*(2), 211-219.

Witt, E.A., Donnellan, M.B., & Orlando, M.J. (2011). Timing and selection effects within a psychology subject pool: Personality and sex matter. *Personality and Individual Difference, 50*, 355-359.

Wundt, W. (1907). Outlines of psychology. Leipzig: Wilhelm englemann.

Zelenski, J. M., Rusting, C. L., & Larsen, R. J. (2003). Consistency in the time of experiment participation and personality correlates: A methodological note. *Personality and Individual Differences*, *34*(4), 547-558.