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# The effect cognitive load has on eye blinking

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**Abstract**

The present study investigates the theory that blink rate decreases as cognitive load increases. 30 subjects participated in one of two experiments, containing four conditions: Condition A involved four blank screens, B was the presentation of one object, C involved the presentation of 24 household objects paired with congruent audio files and D was similar but objects were paired with incongruent audio files. Experiment two differed from experiment one by including longer audio files. The results were that blink rate significantly differed across the conditions in both experiments, $p<.05$. Condition A produced a significantly higher blink rate in both experiments, $p<.05$. Findings showed that manipulation of the lowest cognitive load produced the highest blink rate which supports existing research.

## Introduction

Are eyes the window to the soul? This is a question that is explored in many ways by people from a wide range of academic backgrounds. There are many different parts of the body that can reflect how a person is feeling, more obvious parts include the mouth for smiling and the cheeks for blushing. The eyes are a somewhat more mysterious indicator of a person's feelings and can say a lot more about how a person feels than many people may think. There are some people that believe that the eyes can say much about the mood you are in, whereas other people believe that the eyes can tell us a lot about a person's mental processing. The phenomenon that is explored in this piece of research is whether eye blinking can tell us about how, or if, a person is processing information.

We blink all the time, blinks are very frequent, visible and typically unconscious. There are three main types of blinks as defined by Stern and Dunham (1990): (a) ***reflex blinks*** (in response to something invading the eye), (b) ***voluntary blinks*** (as a result of a decision to blink), and (c) ***endogenous blinks*** (due to perception and information processing). Endogenous eye blinks are the focus of interesting psychological research. Endogenous (meaning "originating from or due to internal causes") blinks occur during reading or speaking and reflect changes of attention and changes in thought processes. The more attention required by a task, the fewer endogenous blinks occur. These are the blinks that are of interest to us in this piece of research. Many studies have linked blink rate to cognitive load during tasks such as reading (Drew, 1951); typically blink rate and cognitive load are found to be inversely proportional. This relationship can be seen in a surgeon who is performing surgery; their blink rate is greatly reduced compared to their blink rate in a general conversation and this is because their cognitive load is at a maximum (Wong, 2002). Cognitive load is a term used in cognitive psychology to illustrate the load related to the executive control of working memory. It is manipulated by increasing or decreasing information for the brain to process i.e. increased visual/audio information will lead to increased cognitive load (Chandler & Sweller, 1991).

The main theory that has evolved from previous research is that we blink more when cognitive load is at its least because we feel we can blink and not miss anything. In this current study, there are four conditions, and each condition manipulates a different amount of cognitive load. The research question is - does cognitive load affect blink rate? It is expected that the highest blink rate will be seen during the condition which manipulates the least amount of cognitive load. In contrast, we should see the least amount of blinks during the condition that generates the most cognitive load causing the participant to concentrate more. The current study will review existing research relating to relationships between cognitive load and blink rate, it will then report on an experiment that manipulates cognitive load to see if past findings can be replicated. There has been some, but not any extensive research into this subject area so this research paper will be important for supporting or disagreeing with any existing research.

### Related research

The research into this particular area is limited as it is not a hugely popular or easy subject area to be investigated. It is important to discuss the research that has been previously conducted as this existing research has been the motivation behind the current study. Nakano et al (2009) conducted a study in which they aimed to find out whether spontaneous eye blinks occurred more regularly in spaces where visual attention was not required. To test this prediction, they examined the spontaneous eye blinks of 14 subjects while they viewed two silent video clips and listened to a narrative. One clip was taken from the television programme ‘Mr Bean’, a British comedy which has an attractive story and was easily understandable without sound. The other video was taken from background videos of landscapes or tropical fish as a control that provided no story development, but only constantly changing scenes. The short narrative was taken from an audio book of ‘Harry Potter’ as another control that had a strong story but lacked any visual stimuli. The stimuli were chosen to test the hypothesis that eye blinks become synchronised with the visual stimuli so as to cause minimal loss of critical visual information i.e. participants would blink less during the rich, strong visual stimuli and would blink more when there is just audio information as the eyes are not needed.

Nakano and his colleagues used Electrooculography (EOG) to record the eye movements during the experiment. When the participant blinked, the graph of the EOG would display it as a peak. EOG is being used in the current study so looking at Nakano’s results gives a good idea of whether this technique is effective. Nakano found that spontaneous eye blinks were synchronised both within and across subjects when they viewed the same story. This blink synchronisation wasn’t observed when they viewed the background video’s that didn’t contain any story or when they listened to a narrated story. Thus, the blink synchrony occurred only when subjects had to follow a storyline by extracting information from a stream of visual events. They found that, as expected, the blink rate increased during scene breaks and they concluded that the blinks were selectively generated as a result of cognitive processing triggered by the explicit break. Previous studies support these findings that blink timing is related to explicit attentional breaks (Hall 1945; Drew 1951; Stern et al. 1984; Fogarty & Stern 1989; Fukuda 1994).

The results of Nakano’s study suggest that we actively search for the implicit timing which is appropriate for blink generation while watching video streams. Synchronous blinks selectively occurred at frames that seemed to be of lesser importance and scenes in which cognitive load was minimised. Nakano concluded that humans share a mechanism for controlling the timing of blinks that searches for the appropriate timing to prevent the loss of critical information from the flow of visual information. The current study tests the conclusion Nakano came to by using conditions that have varying levels of cognitive load. One of the conditions is a series of blank screens, which should in theory generate the least cognitive load and according to Nakano, will produce a high blink rate because participants will view the blank screens as breaks in which they can blink without losing any critical information.

Nakano’s study was based around the idea that we blink less in situations in which we need to absorb more visual information; Volkmann et al (1980) provided research that supports the idea that visual information is suppressed when we blink which in turn causes us to blink less when there is increased visual information. Volkmann hypothesised that a central inhibitory signal must accompany each blink to suppress vision and thereby minimise its perceptual consequences. To test their hypothesis, they placed a fibre-optic bundle against the roof of the mouth to present light through the back of the eyeball to the retina. Opaque goggles were used to eliminate all other sources of light so that the only visual stimulation arrived through the back of the eye. Volkmann and his colleagues found that visual sensitivity to the light was reduced during a blink even though the light source itself was never altered. These results show that vision is indeed suppressed around the time of a blink and that this suppression is partly the result of a central (opposed to optic) inhibitory mechanism. Subsequent studies found that the magnitude of visual suppression increases as blink amplitude increases (Stevenson, Volkmann, Kelly, & Riggs, 1986). As visual input is suppressed during eye blinks, it is not surprising that a lot of research has found that people reduce their blink rate during visually demanding tasks, presumably in order to minimise the risk of missing important information (Baumstimler & Parrot, 1971; Drew, 1951; Kennard & Glaser, 1964; Stern & Skelly, 1984).

It is presumed that people are not often aware that blinking interrupts their visual flow of information, but earlier research suggests that the human information processing system does take these interruptions into account when people are involved in visually demanding tasks. This can be seen in a study conducted by Ponder and Kennedy (1927); they found that people blink less frequently when performing tasks involving visual activity such as reading than during non-visual activities such as conversation. Ponder and Kennedy provided the first evidence that blinks are centrally controlled and are linked to cognitive states. Drew (1951) furthered this research by providing a more direct examination of the relationship between blink rates and the visual demands of a task. The experiment he conducted tested the hypotheses that subjects with higher blink rates will be less efficient in performing visual tasks and more likely to have accidents (Lawson, 1948) and that individual variations in blink rate should reflect the difficulty of a visual task. Drew asked participants to perform in a tracking task where they were required to trace a straight or oscillating line while their blinks were monitored. It was found that as the task got more difficult, participants blinked less frequently than they did under resting conditions. It was observed that participants tended to inhibit blinking completely during periods of maximum task difficulty, spacing their blinks so that they occurred just before or just after these periods. Drew found no relationship between participants' relative blink rates and their relative accuracy on the tracking task, but his study does support the claim that eye blinking is controlled by a central human information processing system based on cognitive demands that we may be unaware of (Ponder and Kennedy, 1927).

More research on the phenomena of blinking comes from Fred Cummins. Fred Cummins has conducted numerous amount of studies, all of which investigate what blinks can tell us. Cummins (2001) conducted a study in which he tested this statement. He examined 20 dyadic conversations of 15 minutes each. Each pair sat facing one another with a video camera behind each participant so that the matched video streams provided full facial observations throughout. The conversants were well known to each other, and the conversation was free and unscripted. Each video was annotated which involved frame by frame observation of each participant, with notation of the time and type of each blink. Cummins found that a participant blinked more each time he/she was experiencing lexical difficulties. This suggests that blinking may signal increased cognitive load, and hence means that increased cognitive load means more blinking, however a causal relationship was not established in this study. The results found by Cummins are preliminary and incomplete, but they do suggest that blinking in naturalistic communicative situations is worthy of study. Cummins' work also suggests that it is at least plausible that the factor occasioning a fall off in blink frequency is not cognitive load per se, but the need to attend to the visual properties of the environment.

Assessing eye blinks can tell us about how much processing is occurring during a particular task. Fogarty & Stern (1989) provided some earlier research about processing in which information about the timing of spontaneous eye blinks was abstracted while subjects performed a detection and identification task. They found an interesting association between saccades and blinking. Saccades are quick, simultaneous movements of both eyes in the same direction. They found blinking to be time-linked to saccadic eye movements in a way that would minimise the disruption of visual information processing. Another approach by Stern and his colleagues involved the recording of blink-rate, duration and latency while individuals were engaged in a modified Sternberg task (Goldstein, Bauer & Stern, 1992). A lower blink rate was found for a six-item than a two-item memory set. The authors suggested that the lower blink rate reflects the greater attention demanded of subjects performing the more difficult visual task involving six-items. Therefore, these results suggest that in a more general sense, if someone blinks less during a task, they are likely to be processing the information at a higher level and concentrating more. The problem with this statement is that you have to distinguish between the different types of blinks as someone may be blinking more as a result of an irritant in their eye but may still be processing the information. However, this is something you have to overcome in all experiments involving blink rates.

**Applications of findings**

The obvious question that may be asked when it comes to finding out how a person’s blink rate is affected by their cognitive load is why is it important? There are some people in the world who cannot communicate to let others know whether they understand something. For example, children with cerebral palsy are often left unable to communicate in any form. Finding out if blink rate decreases during higher levels of cognitive load, will let us gain an insight into whether individuals who can’t communicate are in fact processing the information the same as other people. This is important because it is often presumed by many people that just because someone can’t communicate, this means that they don’t understand what’s going on. Being able to understand more fully about how someone who can’t communicate processes information will lead us to be able to create forms of communication for them so that their needs can be known to the people around them. Knowing how a person’s blink rate correlates with their cognitive load will also help us know things about other people who temporarily can’t communicate, such as patients in a coma. They may not be able to verbally or physically communicate but maybe their eyes could tell us more about what is going on and blink rate could be used as a measure to tell us more.

There is currently a gap in the existing research as few studies solely focus on finding the relationship between cognitive load and blink rate; many studies observe this relationship passively when looking at other factors that affect blink rate. This study has been conducted to focus only on how cognitive load affects blink rate so that any results found can be reliably due to cognitive load being manipulated and not as a result of any other factors. Another aim of this study is to see the effect of increased audio information as there are few studies that look at audio information as a cause of increased cognitive load. Many studies focus on increasing visual information to make a task more cognitively demanding. The present study does this as well as increasing audio information to see if the same effect is found. It is necessary to exclude all other factors and to just focus on manipulating cognitive load so that nothing else can be responsible for a change in blink rate; this means that results can be applied more accurately.

The more research there is that supports the claim that people blink less in more cognitively demanding situations, the more likely it is that new intervention's can be built on this phenomenon. Knowing how blink rate is linked with cognitive load will be very useful in getting to understand the processing of individuals who cannot communicate themselves how they are processing things. This phenomenon could also be used on coma patients to support or disagree with any findings found by the means of MRI scans i.e. testing a coma patient's blink rate could give a vague indication as to how much function they still have in their brain and would also indicate whether they are still processing information.

### Hypotheses

$H_0$: There will be no difference in blink rate between conditions

$H_1$: There will be a difference in blink rate between at least two of the conditions

These hypotheses have been formed on the basis of past research and this study focuses purely on the effects of cognitive load, it is expected that by manipulating levels of cognitive load differently in each condition there will be a change in blink rate between the conditions.

## Method

### Participants
Originally there were 34 participants but 4 had to be removed as their data was unusable due to problems with the equipment, so using the usable data, the participants were 30 students from Plymouth University. They had a mean age of 21.1 in Experiment One and 19.9 in Experiment Two. They all studied Psychology and were recruited using the participation points system.

### Materials
Electrooculography (EOG) was used to measure participants eye blinks whilst they watched a series of slides on a computer. EOG is a technique in which electrodes are placed around the eyes and one is placed on the ear in order to measure the eye's electrical activity. The experimenter's computer recorded the electrical activity whilst the participant completed the experiment on another computer. A back-up measure of recording eye blinks involved filming all the participants using a webcam while they completed the experiment.

### Design
The experiment used a within-subjects design. The dependent variable was the number of eye blinks observed and the independent variable was cognitive load. The amount of cognitive load was manipulated in each condition.

**Procedure**

Experiment One was set in a small room with a desk and two computers. One computer ran the experiment and this is where the participant sat. The other computer recorded the EOG activity and recorded a video via webcam throughout each experiment. The EOG and webcam were put in place so that the eye blinks from each participant could be counted, the eye blinks were counted but the different types of blinks weren't distinguished between. Each participant was firstly handed an information sheet to read and sign (Appendix A), they were then asked to type their subject number and age into the experiment program. The experimenter attached two electrodes below the eye and one electrode on the ear. Each electrode was filled with gel to permit electrical activity to be recorded and they were stuck to the participants face with sticky tape. After the electrodes were in place, the experimenter began recording the EOG along with a webcam recording on one computer and the participant was asked to begin the experiment by pressing the space bar on their computer. The experiment began with a loud beep lasting 250ms and then the different conditions proceeded, the loud beep was repeated between each of the conditions and also at the beginning and the end of experiment. Condition A was made up of four repetitions of a 30 second blank slide, and the blank slide appeared between each of the other conditions. Condition B was a slide showing one of the 24 objects that were used in the experiment for two minutes. A list of these objects can be found in Appendix B. Condition C consisted of the 24 objects appearing in a randomised order, each accompanied by an audio file stating the name of the object, e.g. a picture of an apple was accompanied by a person saying 'apple'. Condition D consisted of the 24 objects being paired with the wrong names in a randomised order, e.g. a picture of an apple would appear and was accompanied by a person saying 'sock'. Conditions B,C and D were presented in a randomised order for each different participant, and Condition A (30 second blank slide) was repeated between each of the other conditions and at the beginning and end of experiment. Figure 1 below shows an example of how one experiment might have been experienced by a participant.

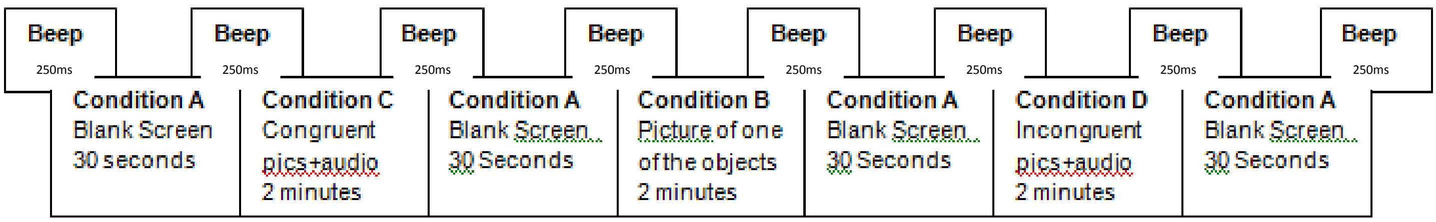


**Figure 1:** An example of how the experiment may be displayed for one participant.

The figure above shows how the experiment should have been run along with the timings, due to a problem in the experiment, Conditions C & D actually ran for 150seconds, but when the results were analysed only the blinks in the first 120 seconds for conditions C and D were counted. This means that all participants did see 24 objects, but the number of objects seen in the 120 seconds that was analysed would have been 20 (80% of 24). The experiment actually lasted a total of nine minutes and the end of the experiment was signalled by a screen saying 'Thank You!' At the end of the experiment, the experimenter pressed a button to stop recording the EOG and the video, and the electrodes were carefully removed from below the participant's eye and ear. The participant was then given a debrief

(Appendix C) and was given the chance to ask any questions regarding the experiment.

Experiment Two had a similar set up; the only difference was the audio files used. Instead of just naming the objects, the audio files described each object, a list of the descriptions used can be found in Appendix D. All the sentences were kept at similar levels of complexity in order to manipulate similar amounts of cognitive load. The conditions and the beeps were exactly same and still in a randomised order. The pictures and audio files were also still presented randomly.

A copy of the participant's signed consent form can be found in Appendix I.

## Results

### EOG data

To draw any conclusions from this study, the number of blinks needed to be found in each experiment to distinguish any difference in blink rate between conditions. The participant's blinks were recorded using EOG; they were also filmed with a webcam whilst completing the experiment. The EOG recordings proved to be un-usable as many of the participants' EOG data was unreliable and as the same measure needs to be used for all participants, it was necessary to manually count the blinks for each participant across the conditions. The videos from which the data was taken can be found in Appendix H.

### Description of conditions

Condition A refers to the 4x30 second blank screens, Condition B refers to the 2 minute presentation of one of the 24 objects, Condition C refers to the congruent condition in which objects were paired with the correct audio files, and Condition D refers to the incongruent condition in which the objects were randomly paired with the wrong audio files.

### Results of Experiment One

Descriptive statistics for the conditions in Experiment One are given in Table 1. Raw data are available in Appendix E.

**Table 1**: Mean, standard deviation and range of eye blinks counted per condition within Experiment One. (n=15 for each condition).

| Condition | Mean | SD | Range |
|---|---|---|---|
| A | 51.2 | 28.92404 | 111 |
| B | 44.7 | 23.82516 | 89 |
| C | 39.4 | 24.51180 | 91 |
| D | 39.0 | 24.77902 | 66 |

Table 1 shows that there is a difference in eye blinks across conditions as expected. Specifically, Conditions C&D produced the least amount of eye blinks suggesting that in fitting with existing theories, these conditions manipulated the highest levels of cognitive load. It can also be seen that the range of eye blinks within each condition is large which could affect the validity of the results and also suggests the presence of individual differences.

A one-way analysis of variance (ANOVA) for repeated measures, for within-subjects factor of cognitive load (four levels – A, B, C, D) indicated that there was a significant difference found in the number of blinks between the four different conditions, $F(3,3.971)$, $p<.05$. Follow-up analysis using the Least-Significant Difference (LSD) method revealed there were significant differences between conditions A&C, A&D and B&C at $p<.05$. There were no significant differences found between the other conditions at $p<.05$ (the full statistical output can be found in Appendix G).

The proportion of eye blinks in each condition is illustrated in figure 2.

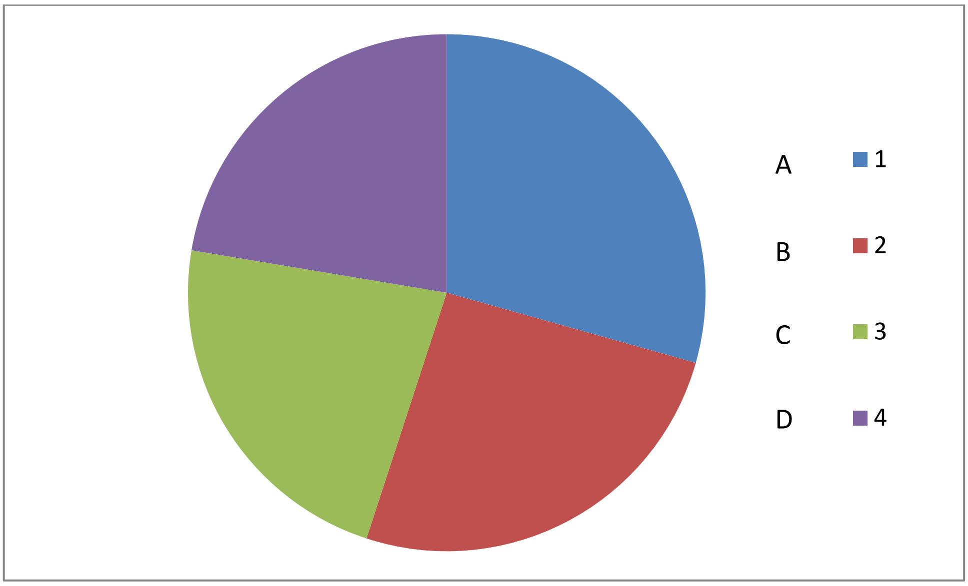


**Figure 2:** Pie chart of the proportion of mean blinks observed for each condition across the experiment (n= 15 for each condition).

The data in figure 2 generally shows that the proportions of blinks in Conditions C&D were significantly smaller than in the other conditions. The results supported this observation, finding that the proportion of blinks in Condition C was significantly smaller than Condition's A&B, $p<.05$ and also finding that in Condition D the proportion of blinks was significantly smaller than Condition A, $p<.05$.

The hypotheses' for this experiment are:

**$H_o$: no difference in the amount of eye blinks between conditions.**

**$H_1$: at least two conditions are different**.

$H_0$ can be rejected and $H_1$ accepted.

**Results of Experiment Two**
Descriptive statistics for the conditions in Experiment Two are given in Table 2. Raw data are available in Appendix F.

**Table 2:** Mean, standard deviation and range of eye blinks counted per condition within Experiment Two. (n=15 for each condition).

| Condition | Mean | SD | Range |
|---|---|---|---|
| A | 44.1 | 20.44109 | 77 |
| B | 38.0 | 20.19194 | 82 |
| C | 34.8 | 16.99244 | 69 |
| D | 35.6 | 13.97856 | 45 |

Table 2 shows that there is a difference in eye blinks across the different conditions. Similarly to Experiment One, Conditions C&D have the least mean amount of blinks when compared to the other conditions. Also similar to Experiment One, the range for each condition is large which could affect the validity of the results.

A one-way analysis of variance (ANOVA) for repeated measures indicated that there was a significant difference found between the number of eye blinks in each condition, $F(3,3.319)$, $p<.05$. Follow up analysis using the LSD method revealed that there were significant differences in the number of blinks between Condition A&B, A&C and A&D at $p<.05$. There were no significant differences found between the other conditions (the full statistical output can be found in Appendix G).

A pie chart showing the proportions of blinks observed in the different conditions is illustrated in Figure 3.

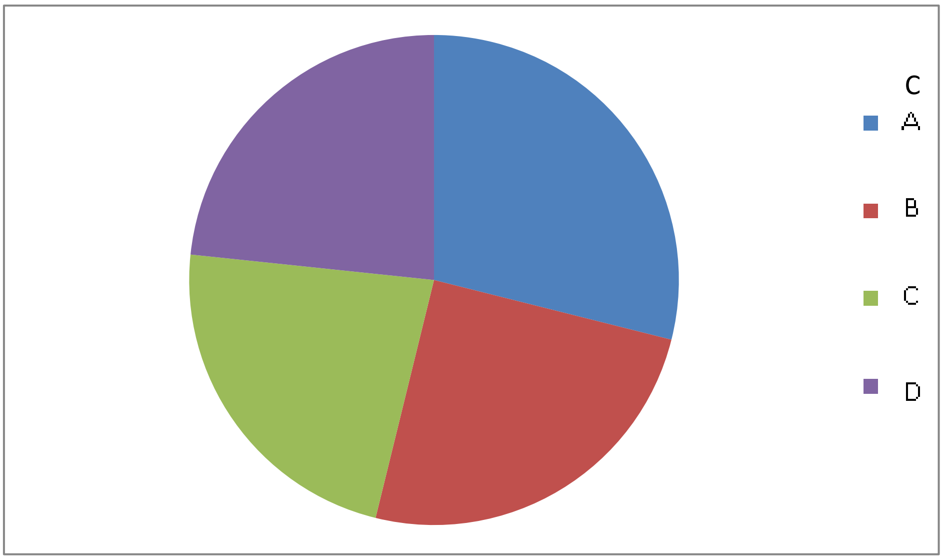


**Figure 3:** Pie chart of the proportion of mean blinks observed for each condition (n= 15 for each condition).

The data in figure 3 shows that the number of blinks observed in Conditions B, C and D were a lot smaller than the number of blinks observed in Condition A. This was shown in the results as Conditions B, C and D were all significantly different from Condition A, $p<.05$. Conditions B, C and D weren't found to be significantly different from each other, $p>.05$.

The hypotheses for Experiment Two were the same as Experiment One, therefore $H_0$ can be rejected and $H_1$ accepted.

**Comparing the main effects from Experiment One and Two**
A one-way analysis of variance (ANOVA) for between-subjects effects found that there was no significant difference for the condition and experiment interaction, $F(3,0.225)$, $p>.05$. This would suggest that the two experiments didn't significantly manipulate cognitive load differently. The ANOVA for within-subjects effects found that there was a significant difference in blink rate between all the conditions across both experiments combined, $F(3, 7.201)$, $p<.001$. Follow up analysis using the LSD method revealed that there were significant differences in the number of blinks between Conditions A&B, A&C, A&D, and B&C at $p<.05$. These results suggest that when the eye blinks from both experiments were combined for each condition, the blinks in Condition A were significantly different from all the other conditions (full statistical output can be found in Appendix G). These results show that cognitive load was successfully manipulated in each condition, and Condition A manipulated the lowest level of cognitive load as it displayed the highest blink rate.

## Discussion

**Implications of results**
Before discussing the implications of the results, it is important to point out that the EOG wasn't the measure used to count the number of blinks during the experiment. Originally, the EOG was going to be used to show the amount of blinks, but the EOG proved to be an unsuccessful measure. The EOG worked well on some participants but picked up too much noise on other participants, making it impossible to distinguish which peaks correlated to blinks. As the measure used needs to be the same for all participants, it was necessary to discard the EOG recordings and simply use the video recordings to count the eye blinks manually. This proved to be a more time consuming measure but it was certainly more accurate than relying on the EOG because the EOG picked up any movement and not just eye blinks. When deciding to use the EOG to record the number of blinks, accuracy was always going to be a potential issue which is why a video recording was taken of the participant as well, so that eye blinks could be counted manually if all else failed. Two people counted the blinks individually to minimise the chance of counting the wrong number of blinks and also to try and avoid a situation where the person counting the blinks blinked at the same time as the participant, causing a blink to be missed. Manually counting the eye blinks also gave the experimenter a chance to observe each participant's patterns throughout the experiment which gave the experimenter more information than just the number of eye blinks. For example, it was noted that in both experiments, participants produced a flurry of blinks at the beginning of the presentation of a blank screen; this will be discussed in more detail later.

The findings were consistent with the experimental hypothesis that there would be a difference in blink rate across the conditions for each experiment and the hypothesis was therefore accepted. Experiment One produced a significant difference between the number of blinks observed in each condition, $p<.05$. A follow-up analysis found that Condition A was significantly differently to Conditions C & D. Condition A was the condition which was made up of four 30 second blank screens and was expected to produce the highest blink rate as it was designed to manipulate the least amount of cognitive load. This appears to be the case in this experiment as the mean number of blinks was significantly higher in Condition A than in Conditions C & D. There was also a significant difference found between Conditions B & C, $p<.05$. This was also expected as Condition B was not very cognitively demanding as it was just the presentation of a single picture for two minutes, Condition C had many pictures along with audio files so would have been expected to be more cognitively demanding which appears to be true in this instance. There were no significant differences found between Conditions A and B, which was expected as Condition B wasn't designed to be much more cognitively demanding than Condition A, and they both included minimal visual information and no audio information. The lowest blink rate was found in Conditions C and D, this can be explained by these conditions having the most audio and visual information meaning they were the most cognitively demanding. The results of Experiment One mean we can conclude that the present study supports past research that blink rate decreases as cognitive load increases.

Experiment Two found significant differences between blink rates in the conditions, $p<.05$. Follow-up analysis found that Condition A was significantly different to all the other conditions, $p<.05$, but the other conditions weren't significantly different from each other. These results suggest that similarly to Experiment One, Condition A manipulated the least cognitive load and therefore produced the highest blink rate. Again, this result was expected as Condition A was made up of blank screens which should in theory generate very little cognitive load. Interestingly, in Experiment Two, the other conditions didn't significantly differ from each other like they did in Experiment One, which could be due to individual differences within each group. It was predicted that Condition B would significantly differ from Conditions C and D as it was a lot less cognitively demanding, but the predictability of Conditions C and D may have affected the blink rate observed. Like in Experiment One, Conditions C and D produced the lowest mean blink rate compared to Conditions A and B which were a lot less cognitively demanding.

One outcome that was expected was that Experiment Two would produce a lower mean blink rate for each condition compared to Experiment One. This was observed and was due to the second experiment being more cognitively demanding than the first experiment. Experiment Two was set up to be more cognitively demanding as a test to see whether listening to more complex items manipulates a higher level of cognitive load and therefore a lower blink rate. It can be concluded that this study indicates that more audio information led to Experiment Two being more cognitively demanding. However, there was no statistical backing for this as there was no significant difference found between the blinks observed in each experiment; it can only be observed from overall means in the descriptive statistics.

The use of congruent and incongruent information was used in Conditions C and D to find out whether different types of information were more cognitively demanding. In both experiments, no significant differences were found between Conditions C and D, suggesting that congruent and incongruent information requires similar levels of cognitive load within the conditions in these experiments. It was originally thought that participants viewing the incongruent condition may start to lose concentration and blink more because humans tend to give up on things that don't make sense. This however wasn't the case in this particular study. To find an effect, it may be necessary to increase the complexity of the congruent and incongruent information and to also have more participants.

**Critique of the method and proposed solutions**

When conducting studies on blink rate, there is always going to be individual differences within the participants. Blinking is a highly individualised activity and this was apparent in the current study as some participants had a blink rate that was a lot higher than others. For example, one participant might blink 40 times during a condition whereas someone else might blink 100 times. This variation in blink rate for each condition was shown in the range of the eye blinks which was large for each condition in both experiments. To minimise individual differences, the same participants participated in each condition within each experiment. To minimise individual differences further, Declerck (2006) suggested that participants could be asked to fill out a Personality Trait questionnaire before hand as he found evidence that a personality trait reflecting control perception may have a biological component for eye blinking. Two different sets of participants were used for each experiment which is why when both experiments were compared, individual differences would have been a factor.

One main problem with the present study is that there weren't many participants in each experiment. The present study started off with 34 participants, but this was reduced to 30 as four of the participant's data were unusable. In order to gain results that can be generalised and applied to the population, it is necessary to have a larger number of participants that incorporate many different types of people. In future studies, more participants would need to be used, giving more reliable results.

This experiment can also be criticised on one of the methods used to collect the results. EOG was the original method of gaining the blink rate but as mentioned this proved unsuccessful as previously mentioned. To carry on using the EOG as the method of gaining blink rate would have given inaccurate results as the EOG didn't give reliable data for all participants. The EOG electrodes also many have been responsible for irritating people's eyes and possibly causing them to blink more. The method used in the end was to manually count the blinks. The obvious problem with this was human error; it was attempted to minimise this by getting two people to manually count the blinks in the videos and any discrepancies between the two peoples findings were solved by counting the blinks in that particular video again. Manually counting the blinks also meant that some quick blinks had to be watched again as they weren't clearly distinguishable blinks. On the upside, manually counting blinks, gave the experimenter a clearer view of how participants behaved during the experiments because factors such as facial expressions were observed. From seeing participant's facial expressions, it was clear that most participants stayed focused for the duration of the experiment, and only a few participants lost concentration all together. One measure that could have been used instead of both the EOG and manually counting the blinks, is the eye tracker. The eye tracker is measure of counting blinks via a computer program that would have given more accurate results and would be the measure used in future studies for increased ease and accuracy.

Many studies on blink rate lack real-life application. This may be the case in this study as it was set in a small laboratory like room, this may mean that the results cannot be generalised out of the laboratory environment. Participants were also aware of being filmed whilst completing the study which may have had some effect on the way they acted. For example, one participant messed around pulling faces into the camera which wouldn't have happened if they were in a naturalistic setting not being filmed. Participants were told that eye movement was being recorded but not that it was their eye blinks in particular that were being recorded, however, a few participants did look over at the screen displaying the EOG graph on the other computer during the experiment and then kept blinking and moving their eyes to try and change the graph. Obviously this was an unwanted effect and in future experiments it would be a necessary change to keep the EOG graph hidden from the participants view.

**Relation to other studies**

Many of the results found in this study are similar to that found in other studies and they can be used as further support for the theory that an increase in cognitive load leads to a decrease in eye blinks. A particular similarity to Nakano's study was found in the highest blink rate being found in the condition made up of blank screens. Nakano et al (2009) found that in his study, blink rate increased during breaks from the stimuli and his theory behind this phenomenon is that people felt they could blink without missing anything. In the current experiment, the condition that produced the highest blink rate in both experiments was Condition A, which was made up of four 30 second blank screens. It is most likely that the participants viewed the blank screens as a break from the other stimuli and therefore their blink rate increased as they felt they could blink without missing any important visual information. It was also observed that many participants experienced a flurry of blinks at the initial presentation of the blank screens which is further support for the participants viewing them as a break from the stimuli and therefore a chance to blink without missing critical information.

The results of the present study show that the participants blinked more during the conditions that required the least attentional demands (Conditions A&B), as these conditions contained little or no audio/visual information so in turn manipulated the least cognitive load. The findings of the present study support Drew (1951) and Poulton and Gregory (1952), who suggest that blink rate, can serve as an indicator of the attentional demands of a cognitive task. The more attention a task requires, the less often people blink. These early studies of blink rate during continuous tasks provided evidence that the attentional demands of a task are reflected in blinks' occurrence. Later experiments included a more detailed investigation of blink timing and blink characteristics that showed more specifically how blinks are related to the cognitive demands of a task. One such experiment was conducted by Baumstimler and Parrot (1971). They asked participants to perform a choice reaction time task in which they responded by pressing one of five keys that were paired to the presentation of specific digits. On some of the trials, the digits were paired with a peripheral stimulus that served as cue to inhibit making a response on that trial. The experimenters found that in keeping with existing research, spontaneous blinking was inhibited during stimulus presentation. They also found that a high proportion of the blinks tended to be deferred until after the participants had made their response on the keys. Based upon these findings, they concluded that blink inhibition was tied to inhibition of making a motor response; when responses are inhibited, blinks are also inhibited, but when participants make a response, it releases this inhibition so that blinks then occur. Baumstimler and Parrot's (1971) interpretation of their results contradicts the idea that blinks are a useful indicator of underlying cognitive processes, instead suggesting that blink are tied to motor processes. However, these results are also consistent with the hypothesis that blinks were inhibited while participants processed and made decisions about whether or how to respond to stimuli and then programmed those responses. This hypothesis is consistent with the idea that blinks do reflect cognitive processes.

Increased cognitive load has been linked to increased amounts of visual information in many previous studies (Wong, 2002; Drew, 1951); in the current study cognitive load was increased by means of increasing audio and visual information. Cummins (2011) found that lexical difficulties were also linked to higher cognitive load which could have certain implications for the present study. Cummins (2011) found that participants blink rate decreased when experiencing lexical difficulties in producing longer sentences whilst in a conversation. In the current experiment, it was found that blink rate decreased in Experiment Two when compared to Experiment One for conditions that contained audio information. Experiment Two differed from Experiment One only by including more complex audio files to listen to. Cummins' results may also have an implication for listening to more complex sentences as well as the participants producing them. However, there was no significant difference found between the blink rates observed in each experiment; it was only seen that there was a lower mean number of blinks in Experiment Two. In order to find a significant difference, it may be necessary to make sentences even more complex in future studies to find whether listening to complex audio information does increase cognitive load which in turn has an effect on blink rate. Cummin's results suggest that in order to engage a higher level of cognitive load, it is necessary to take part in tasks that involve more complex phenomena which cause you to think.

Two of the conditions within both experiments were designed to have an increased amount of visual information. Conditions C and D were made up of 24 different objects being presented on the screen one at a time for five seconds. Volkmann et al (1980) found that when we blink, visual information is suppressed. The lowest blink rates were found within these two conditions with the most visual information. According to Volkmann, this is due to participants having a central system which makes them blink less in times of increased visual information. This finding in the present study is also supported by other studies that suggest people reduce their blink rate during visually demanding situations in order to minimise the risk of missing important information (Baumstimler & Parrot, 1971; Drew, 1951; Kennard & Glaser, 1964; Stern & Skelly, 1984). In relation to the present study, participants may have decreased their blink rate so that they didn't miss the presentation of any of the objects.

## Conclusions

To conclude, the experimental hypothesis stating that there would be a difference in blink rate across conditions that manipulated cognitive load was proved correct and accepted. The present study filled a gap in existing research; there was a gap because there have been few studies that focused only on cognitive load being manipulated to find the effect on blink rate. The results of this study have provided support for existing research and also support for existing theories. The present study aimed to focus solely on the effect cognitive load has on blink rate, eliminating all other factors; it did this successfully. The only factors that could have affected blink rate that were beyond our control were individual differences and the unnaturalistic setting of the study. As cognitive load was the only independent variable, the findings can be said to be due to the manipulation of cognitive load alone. This means that the variance in blink rate was caused by cognitive load and inferences can be made from this. The findings of this study were that the conditions that manipulated a higher cognitive load were the conditions that produced the lowest blink rate, supporting the theory that as cognitive load increases, blink rate decreases. This was further support by finding that the most blinks occurred in the condition made up of blank screens which manipulated the least cognitive load. The present study also supports a sister theory states we also blink more during situations of decreased visual stimuli as we feel we can blink without missing anything (Nakano et al, 2009).

The implications of the findings of this study and others are that we can start to understand more about the processing of people who cannot tell us how or if they are processing information. The findings can also be used to design interventions that will focus on engaging people to focus on certain stimuli. Studying the eye, and eye blinks is an interesting phenomenon that is starting to generate more interest in the research community as people want to learn more about the way the human mind works. The findings of the present study can be made better by repeating the study with more participants and with more engaging stimuli.

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