Master's thesis

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Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Psychology

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# Adapting to task difficulty in audio and visual distraction over three days

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Supervisor: Dawn Marie Behne
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# Abstract

This study investigates the effect of auditory, visual, and audiovisual distraction on Norwegian university student's performance on easy and more difficult mathematical calculations, over the span of three days. The student's performances were measured by reaction time, how many tasks they managed to complete (efficiency), and how many correct answers they had based of their completed tasks (accuracy). Both auditory and visual distractions are found to negatively impact performance on various cognitive tasks, including mathematical calculation (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013). The perceptual load model and previous studies indicate that visual distractions might have less of a negative impact on difficult visual tasks, compared to easy visual tasks (Forster & Lavie, 2008; Lavie, 1995; Lavie, 2005; Tellinghuisen & Nowak, 2003). Furthermore, previous studies have found evidence for long term habituation to visual distractions while doing a visual task (Turatto & Pascucci, 2016; Vaina et al., 1995). Hypotheses were created based on the previous studies and tested using an experimental design. The results, unexpectedly, showed no evidence for a negative effect of the auditory and visual distraction on the calculations. The distraction conditions actually showed lower reaction times, higher efficiency, and higher accuracy than the control condition. There was some evidence that difficult tasks could be more resistant to auditory and visual distraction than easy tasks. Lastly, some evidence for habituation to auditory and visual distraction were found. The results are discussed and suggestions for further research are given.

*Keywords*: Visual distraction, auditory distraction, audiovisual distraction, mathematical calculation, perceptual load model, habituation, adaptation

## Sammendrag

Studien undersøker effekten auditive, visuelle og audiovisuelle distraksjoner har på norske universitetsstudenters prestasjoner på enklere og vanskeligere matematiske kalkulasjoner, over et tidsspenn på tre sammenhengende dager. Studentenes prestasjoner ble målt ved hjelp av reaksjonstid, hvor mange oppgaver de klarte å gjennomføre (effektivitet) og hvor mange korrekte svar de hadde på de gjennomførte oppgavene (nøyaktighet). Både auditive og visuelle distraksjoner har vist å ha negativ effekt på ulike kognitive oppgaver, inkludert matematisk kalkulering (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013). *Perceptual load model* og tidligere forskning indikerer at visuelle distraksjoner kan ha mindre negativ effekt på vanskelige visuelle oppgaver, sammenlignet med enkle visuelle oppgaver (Forster & Lavie, 2008; Lavie, 1995; Lavie, 2005; Tellinghuisen & Nowak, 2003). Videre har tidligere studier funnet evidens for langtidshabituering til visuelle distraksjoner under visuell oppgaveløsning (Turatto & Pascucci, 2016; Vaina et al., 1995). Hypoteser med grunnlag i tidligere forskning ble laget og testet i et eksperiment. Resultatene viste, uforventet, at det ikke var noen negativ effekt av de visuelle og auditive distraksjonene på kalkuleringen. Distraksjonsbetingelsene viste faktisk lavere reaksjonstid, høyere effektivitet og høyere nøyaktighet enn kontrollbetingelsen. Det ble funnet noe bevis for at vanskeligere oppgaver er mer resistente mot påvirkning av visuelle og auditive distraksjoner. Til slutt ble det funnet noe evidens for habituering til auditive og visuelle distraksjoner. Resultatene blir diskutert og forslag til fremtidig forskning blir lagt frem.

*Nøkkelord:* Visuell distraksjon, auditiv distraksjon, audiovisuell distraksjon, matematisk kalkulering, *perceptual load model*, habituering, adaptasjon

# Preface

Working on this master’s thesis has been both challenging and very exciting. I have developed my academic skills throughout the entire process of setting up the hypotheses, planning the experiment, recruiting participants, completing the experiment, and writing up the finished thesis. I take with me all these experiences into future work and I consider the learned skills immensely valuable. My interest for cognitive psychology, the human brain, and learning has grown much stronger. There has been a large amount of independent work, but also many fruitful and rewarding discussions with my supervisor and fellow master students. I would like to say thank you to my supervisor Dawn Marie Behne for supporting me and guiding me through every part of the process, and for giving me such valuable and constructive feedback. I have learned so much from you. I would also like to thank my fellow master students for the all the support and for the discussions in the lab; both academically related and otherwise.

Ine Stensholm Elveland,
Trondheim, May 2022

## Contents

# Background

Individuals are exposed to many different sensory events every day. Some events may provide important information, while other events may be distracting. In cognitive load theory (CLT), working memory is thought to have limited capacity to compare, contrast, and organize such sensory events (Sweller et al., 1998). Even though working memory can hold approximately seven items at a time (Cowan et al., 2004; Miller, 1956), it may only be able to work with three or four of these different items simultaneously (van Merriënboer & Sweller, 2005). If new items are presented and considered to be of importance, the information will be stored in long term memory (Kandel et al., 2013). Furthermore, this will take some load of working memory the next time the items are presented. Neural pathways that are frequently used will be strengthened, and neural pathways that are not frequently used will be weakened (Edelman, 1993). After being repeatedly exposed to sensory events that are considered to be irrelevant, habituation to these events can happen, with neural pathways weakening and future activation becoming less likely (Kandel et al., 2013). One can question whether distracting sensory events will continue to be distracting over time, or if there is a possibility for individuals to adapt to such irrelevant sensory events.

Distraction have shown to have a negative effect on performance. In a study, the productivity of office workers was significantly higher when online distractions were blocked from their computers (Mark et al., 2018). However, these distractions were controllable. What about distractions that are less controllable? Some distracting sensory events might, for example, be background noises or flickering lights. Such uncontrollable and irrelevant distractions might have an impact on task performance, but one might also be able to ignore them. This thesis will look deeper into the effect of irrelevant auditory and visual distraction on cognitive performance. Furthermore, the thesis will try to better understand the role of perceptual load in relation to distraction effects; whether task difficulty plays a significant role in the effect the distractions have on cognitive performance. Thirdly, the thesis will investigate the possibility for individuals to learn to ignore irrelevant auditory and visual distraction when repeatedly being exposed to them. Is long-term habituation possible?

## Auditory and visual distraction

The brain is constantly being exposed to both auditory and visual information, some of which can be distracting. In the scope of this thesis, distraction is defined as either auditory or visual sensory events that can possibly impair the performance on a current auditory or visual task. In a study, the effect of visual distraction on students' short-term memory was investigated (Dent, 2010). The participants were asked to remember either four different locations or a color. Participants would watch a fixation cross, then four locations or a color was presented for two seconds. The dynamic visual distraction was then presented for five seconds. The participants decided whether stimuli presented anew was the same as before, or not. In a second version of this experiment, participants would try and recreate the spatial stimulus or choose a colour from a range of colours. In both versions of the experiment the visual distraction had a negative impact on short-term memory, measured by reaction time and accuracy, however, this was only true for color and not for spatial location (Dent, 2010). These results indicate that visual distraction can have a negative effect on short-term memory, and that the negative effect can differ across specific tasks.

In another study, the effect of both moderate and severe dynamic visual distraction on semantic comprehension during silent reading was investigated (Gao et al., 2012). The participants were both younger adults and older adults. The participants would read several different sentences while simultaneously being exposed to visual distraction. Results showed that the visual distraction had a negative impact on the semantic understanding for both the younger adults and older adults when the distractions were severe, but when the distractions was moderate the negative effect on semantic processing was only observed for the older adults (Gao et al., 2012). Thus, the authors conclude that visual distractions can have a negative effect on semantic understanding during reading, and that the age of the participants might play a significant role (Gao et al., 2012). The difference in findings between age groups may also suggest that effects of distraction are modulated by experience.

A review study investigated the effect of irrelevant auditory background noise on children’s performance on various cognitive tasks, and found that both chronic and acute noise had a negative impact on children’s cognitive performance (Klatte et al., 2013). The acute noise had a negative effect on speech perception, listening comprehension, reading skills and short-term memory (Klatte et al., 2013). The chronic noise had a negative impact on verbal tasks and reading (Klatte et al., 2013). Furthermore, the study found that background noise can negatively impact adults’ cognitive performance on such tasks as well, however, the negative effect seemed to be larger for children than for adults (Klatte et al., 2013). Studies like this show that irrelevant background noise can impair diverse cognitive functions, especially with young people.

Another review study also investigated the effect of background noise on young adult’s short-term memory (Beaman, 2005). Participants performed a serial recall task, in which they heard a set of words and recalled them in correct order. Simultaneously, the participants were exposed to irrelevant speech or non-speech background noise. The study concluded that auditory background noise can have a negative impact on young adult's short-term memory (Beaman, 2005). Results like this indicate that irrelevant background noise can impair young adult's cognitive functions; specifically short-term memory.

A third study investigated the effect of more or less emotionally engaging auditory distraction on college students' mathematical calculations (Heim & Keil., 2019). While previous findings have shown that visual distraction can negatively impact the performance on diverse visual tasks, this study tested the cross-modal impact of auditory distraction on a visual task such as mathematical calculation (Heim & Keil., 2019). The participants were presented with three math tasks, one at a time, while simultaneously being exposed to distracting sounds. Right after, the participants would write down the three answers. The math problems were easy addition, subtraction and multiplication tasks (the tasks including only two numbers with one digit each). The study found that the auditory distraction had a negative impact on the visual calculation, and that sounds that were the most emotionally engaging were more distracting than low-arousal distraction (Heim & Keil, 2019).

In a Bayesian model, sensory experience in the external world is based on previous experiences with the same sensory events (Vilares & Kording, 2011). This means that if a current sensory event does not agree with previous experiences, the sensory event will be given more attention and processing in working memory. One study found that auditory musical stimuli that vary in temporal presentation are more distracting than auditory musical stimuli that are temporally predictable (Schlittmeier et al., 2008). The unpredictable stimuli affected both auditory and visual recall of items. A related study found that sounds that break a perceptual pattern are more visually distracting when judging whether presented numbers were even or odd, than sounds that do not break a perceptual pattern. (Parmentier et al., 2011) To sum up, auditory events that are temporally unpredictable are more distracting than auditory events that are temporally predictable.

## Cognitive capacity and perceptual load

The perceptual load model addresses cognitive capacity and the role of perceptual load on cognitive capacity (Lavie, 1995; Lavie, 2005). According to the model, irrelevant information is processed when there is enough cognitive capacity to do so. If the perceptual load of a task demands more cognitive capacity, less cognitive capacity is available to process irrelevant information. The perceptual load of the task will therefore inhibit the processing of irrelevant information, and potentially lead to better performance on the specific task, compared to a task with lower perceptual load. Increased perceptual load can for example involve increasing the attention a perceptual event requires, or increasing the items in a perceptual event (Lavie, 2005).

One study, using a visual search task, investigated whether participants could ignore auditory and visual distraction (Tellinghuisen & Nowak, 2003). The auditory and visual distraction stimuli were either target response-compatible or target response-incompatible. The participants were presented with a fixation point on a computer. Six letters would then appear around this fixation point, and the participants' task was to search for the target letter N or X. In the easy version of the task, the target letter would appear in one spot and the letter O occupied the other five spots. In the difficult version of the task, he letters H, Y, Z, K, and V occupied the five other spots. The visual distraction appeared on either the left or the right side on the computer screen (outside the circle of letters), and were either N or X. Neutral visual distraction were also included in the study, and were either the letter L or T. A female voice read out a letter as auditory distraction.

The study found a negative effect on both reaction time and accuracy for the visual distraction; however, this was only true for the easy version of the task and not the difficult version of the task (Tellinghuisen & Nowak, 2003). These results are consistent with the perceptual load model, where the perceptual load in the difficult tasks inhibits the processing of distraction stimuli. Similar results were found in an earlier study where an increase in relevant visual stimuli, decreased the processing of irrelevant distractions in a visual search task (Lavie & Cox, 1997). Furthermore, the negative effect-pattern on reaction time and accuracy was not found for the auditory distraction (Tellinghuisen & Nowak, 2003). The auditory distraction actually had a larger negative effect on reaction time and accuracy for the difficult task than for the easy task, in the compatible condition. Given these results, one can argue that auditory and visual events either are processed differently or physically separated in the brain. The different sensory systems have their own neural network and their own working memory, according to the basic systems model (Rubin, 2006). Furthermore, this model suggests that the sensory systems communicate with each other while simultaneously working independently. How information from different sensory systems is integrated, however, remains uncertain (Murray et al., 2016). Further research on the effect of both auditory and visual distraction is needed to investigate this further.

The results regarding the auditory distraction from the first experiment were replicated in a second experiment where a non-distractor condition was included (Tellinghuisen & Nowak, 2003). A third experiment investigated the auditory distraction further, this time including white noise as an auditory distraction. The results were the same as in the earlier experiments: the auditory distraction had a larger negative effect on the difficult version of the task, than on the easy version of the task. The study conclusion was a suggestion that inhibition of auditory interference is weakened by higher visual load (Tellinghuisen & Nowak, 2003). To sum up, visual distraction might have a larger distractor effect on easier visual tasks, than more difficult visual tasks, however, the opposite seem to be true for auditory distraction on visual tasks.

The results of this study (Tellinghuisen & Nowak, 2003) indicate that a task with higher visual load can aid in the ability to ignore visual distraction stimuli. In this study, however, the distraction used were task relevant to the degree that both the stimuli to be searched for and the visual distraction were letters. This begs the question to whether a completely irrelevant visual distraction can show the same pattern as a relevant visual distraction. A study using the same experimental design as the study described earlier in this section, investigated exactly this (Forster & Lavie, 2008). The study used a completely irrelevant visual distraction that appeared on the computers screen outside the fixation point with the letters around (Forster & Lavie, 2008). The irrelevant visual distraction stimuli were pictures of different cartoon characters. The results in this study indicated that a completely irrelevant visual distraction had a negative effect on reaction time and accuracy in the visual search task, and the negative effect was similar to the negative effect of a relevant visual distraction. Furthermore, the effect was greater in the easy version of the task than in the difficult version (Forster & Lavie, 2008), lends support to the perceptual load model.

Together, these findings indicate that a visual distraction, be it either relevant or irrelevant to the task at hand, can have a negative effect on the efficiency and the accuracy of a visual task that require some form of cognitive capacity. This knowledge may have an implication on how we view the distraction in different learning situations.

## Auditory distraction, inhibition, and habituation

Distraction can have a negative effect on cognitive performance for specific tasks (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013), and the ability to inhibit irrelevant visual stimuli seems to increase with higher perceptual load on the task (Forster & Lavie, 2008; Tellinghuisen & Nowak, 2003). This further begs the question whether individuals, over time, can learn to ignore irrelevant information while doing a specific task. One can further question if there is a difference between auditory and visual distraction stimuli on such long-term inhibition. Information that is new to individuals is given more attention, and working memory will process and sort this new information (van Merriënboer & Sweller, 2005). Once individuals consider a perceptual event to be irrelevant, however, less attention is given to the event. This habituation is the process where neural pathways in the brain related to a specific event is weakened because the event is considered irrelevant or not important after repeated exposure (Kandel et al., 2013). As such, the probability for the same neural pathways to activate in the future will be lower. What has previous studies found in relation to habituation of auditory distraction?

One study investigated whether university students could learn to ignore irrelevant background noise (Banbury & Berry, 1997). The participants read text passages while simultaneously being exposed to either a complete radio recording, three minutes of the radio recording on repeat, or just random words from that same radio recording. The participants had five minutes to learn the text passage and then recall as much as they could from the passage. A response to the first text passage was followed by a habituation phase with only background noise for 20 minutes. Then they read and recalled a second text passage. The students were not exposed to background noise during recall. The student's accuracy and the amount of time they needed to give their answer were dependent variables. The study found that the speech noise could be habituated to after 20 minutes of exposure (Banbury & Berry, 1997). In a second experiment, habituation happened during 20 minutes when the auditory distraction was office noise without speech (Banbury & Berry, 1997). This means that habituation could happen for both speech and non-speech auditory noise. However, in a third experiment it was found that dishabituation could happen with just five minutes of silence (Banbury & Berry, 1997).

These results indicate that after a period of exposure, adaptation occurs for both speech and non-speech background noise, but there was only evidence of short-term habituation, and dishabituation happened after a short period of time (Banbury & Berry, 1997). In a study investigating neurological adaptation to speech in noise (Khalinghinejad et al., 2019), participants listened to continuous speech for 20 minutes with the background noise changing every three to six seconds. The study found evidence for adaptation to rapidly changing background noise in the auditory cortex, where irrelevant background noise is filtered out and the speech stimuli enhanced (Khalinghinejad et al., 2019). However, if this adaptation can last over a longer span of time, where the subjects are not being exposed to the background noise, is not known. In the study, the attention of the participant did not matter for the adaptation (Khalinghinejad et al., 2019). Furthermore, there may be a difference between passively listening to speech in noise and being engaged in a specific task.

The neural adaptation to background noise, and the effect of engagement in a task while being exposed to this background noise, was investigated in a study with macaque monkeys (Rocchi & Ramachandran, 2020). The monkeys tried to recognize a tone hidden in background noise while either passively listening or being engaged in a behavioral task. The study found that being engaged in a behavioral task led to better adaptation to the background noise, than in the passive listening condition (Rocchi & Ramachandran, 2020). Results like this indicate that task engagement might play a significant role the ability to habituate irrelevant auditory noise. However, given that the participants in the study were monkeys, it is not known whether the same could be found for humans.

Studies that have investigated long-term habituation to auditory distraction in serial recall of items have found no evidence for long-term habituation (Beaman, 2005; Hellbrück et al., 1996). This does, however, not mean that long-term habituation to auditory events cannot happen under other circumstances. A study that investigates the effect of non-speech, auditory distraction on the performance of a task that does not only involve retrieval from memory could therefore bring previous research forward.

## Visual distraction, inhibition, and habituation

Despite evidence that the auditory cortex can learn to inhibit irrelevant auditory stimuli (Banbury & Berry, 1997; Khalinghinejad et al., 2019; Rocchi & Ramachandran, 2020), no evidence for long-term habituation to such irrelevant auditory stimuli during involvement in a task has been found (Beaman, 2005; Hellbrück et al., 1996). What about visual distraction? In one study, evidence for habituation was found when participants were passively exposed to circles with different colours (Won & Geng, 2020). This indicates that only watching the same visual stimuli repeatedly can induce inhibition and habituation to the stimuli. However, one can question whether the same can be said while participants simultaneously are completing a task.

To investigate whether neurons in the visual cortex adapted to noise in dynamic patterns, participants tried to discriminate the movement of a dotted pattern with randomly moving dots as distraction (Vaina et al., 1995). The participants were trained on this task over the span of three consecutive days, with a follow up nine days after the first day. Linearly with training, the participants' performance on direction discrimination improved; the participants gradually became more accurate at discriminating leftward and rightward movement with the training (Vaina et al., 1995). About 200 repetitions were needed to achieve nearly a perfect score, and furthermore, the scores were preserved nine days after the first training session (Vaina et al., 1995). The inhibition of distracting stimuli led to habituation as a consequence of training. Furthermore, the discrimination of upward and downward movement could be learned the same way, but there was no transfer between these two skills (Vaina et al., 1995).

Long-term, and short-term, habituation to visual distraction has also been investigated over three consecutive days in a later study (Turatto & Pascucci, 2016). This study also included a follow up several days later. In a timed-response task, young adult participants indicated the location of a red visual stimulus on a computer monitor. The participants pressed a button as quickly as possible, always keeping their attention on the fixation cross. Grey visual stimuli would appear close in time to the target stimulus to distract the participants from the correct position of the target stimulus. The study found evidence for both short-term and long-term habituation to the distraction stimuli (Turatto & Pascucci, 2016). The complete habituation effect obtained on the first day of experimentation lasted the following two days. This study, and the study above by Vaina et al. (1995), indicate that individuals can learn to ignore visual distraction given training, and that the habituation to the stimulus can last several days.

A third study investigated the ability to ignore visual distraction where both young and elderly adults read paragraphs either with distraction or without distraction (Rozek et al., 2012). The paragraphs were presented sentence by sentence, with the visual distraction placed inside the sentences. The distraction did not carry any semantic meaning to the sentence and was also written in a different font. Eye tracking measured the participants' fixation time on the words, and lastly, the participants completed comprehension test. The study results indicated that both younger participants and older participants learned to ignore the visual distraction, but that the effect was bigger for the younger participants (Rozek et al., 2012). Furthermore, the participants with a higher score on inhibition had more accurate fixation and better comprehension, than participants with a lower score on inhibition. Inhibition was also the strongest moderating factor, compared to working memory, processing speed, and vocabulary (Rozek et al., 2012).

The results of all these studies indicate that inhibition, short-term habituation, and long-term habituation to visual distraction events can occur, and may be easier for younger individuals than for older individuals. Given training, individuals may be able to learn to ignore visual events that are not relevant to them. Habituation does not only seem to rely on inhibition and passive learning, but also relies on active learning and cognitive mechanisms that facilitate learning (McDiarmid et al., 2019). Both inhibitory control; the ability to give attention to important events and ignore irrelevant ones, and working memory are considered to be executive functions, and both inhibition and working memory are key for habituating to irrelevant events (Diamond, 2013).

### Mathematical calculation

In relation to auditory and visual distraction, several studies have focused on either reading, writing, or merely letters as the task stimuli (see Banbury & Berry, 1997; Beaman, 2005; Forster & Lavie, 2008; Gao et al., 2012; Khalinghinejad et al., 2019; Klatte et al., 2013; Rozek et al., 2012; Tellinghuisen & Nowak, 2003), and not many studies have focused on numbers and mathematical calculation (cf. Heim & Keil, 2019). Mathematical calculation involves spatial visualisation and spatial orientation, where an improvement in these skills can improve math performance (Lowrie et al., 2019). In contrast, audiovisual temporal sensitivity is important for reading (Francisco et al., 2017). Thus, mathematical calculation is predominantly a visual task and isolate the visual modality to a larger degree than reading. Furthermore, the isolation of the visual modality makes it easier to differentiate between an easy calculation task and a more difficult calculation task. Mathematical calculation is known to rely heavily on working memory, and therefore demand more than just retrieval from memory (Ashcraft & Krause., 2007). Furthermore, the operation of carrying over in mathematical calculations puts significantly more load on working memory than calculations where one does not have to carry over (Kalaman & LeFevre, 2007). This can therefore be used to distinguish between easy and difficult tasks, which is interesting to look into in relation to the perceptual load model (Lavie, 1995; Lavie, 2005).

### Current study

The current study questions whether auditory, visual and audiovisual distraction will negatively affect the efficiency and accuracy in mathematical calculation, and questions whether math tasks that demand more working memory capacity, as compared to math tasks that demand less working memory capacity, can assist in the ability to ignore irrelevant auditory, visual and audiovisual distraction. Previous studies have found that auditory distraction (Beaman, 2005; Heim & Keil, 2019; Klatte et al., 2013) and visual distraction (Dent, 2010; Gao et al., 2012) can negatively impact cognitive performance on various tasks. These findings suggest that both auditory and visual distraction can negatively impact mathematical calculation performance. The first hypothesis is: auditory and visual distraction will have a negative effect on efficiency and accuracy in mathematical calculation, as compared to no distraction.

The perceptual load model states that the processing of irrelevant information occurs if cognitive capacity is available (Lavie, 1995; Lavie, 2005). Therefore, if a task demands more cognitive capacity, less cognitive capacity is available to process the irrelevant information. Studies have found evidence to support this model (Forster & Lavie, 2008; Tellinghuisen & Nowak, 2003), however, this was true only for visual load on a visual task, and not for auditory load on visual task. Given this information, visual distraction is expected to have a negative impact on a visual task that demands more cognitive capacity, compared to a task that demands less cognitive capacity. The second hypothesis is: the negative effect of visual distraction on efficiency and accuracy is expected to be greater for mathematical calculations with lower difficulty, compared to mathematical calculations with higher difficulty.

Furthermore, the current study questions whether individuals can learn to ignore irrelevant auditory, visual, and audiovisual distraction when doing mathematical calculations, such that the efficiency and accuracy of the calculations increases with training. Previous research has found evidence to support habituation to visual stimuli, both over a short amount of time (Rozek et al., 2012), and over the span of three days (Turatto & Pascucci, 2016; Vaina et al., 1995). There is some evidence for a short-term habituation to auditory distraction as well (Banbury & Berry, 1997; Khalighinejad et al., 2019; Rocchi & Ramachandran, 2020), but not over several days (Beaman, 2005; Hellbrück et al., 1996). The third hypothesis is: the negative effect of visual distraction on efficiency and accuracy during mathematical calculation is expected to decline in the course of day 1 to day 3.

# Method

## Design

To test the three hypotheses presented above, an audiovisual distraction experiment investigating the efficiency and accuracy in mathematical calculation over three days, was conducted. The mathematical calculation tasks consisted of both easier and more difficult addition and subtraction tasks, and there was either no distraction, auditory distraction only, visual distraction only, or audiovisual distraction. The participants reaction times, number of completed tasks, and number of correct tasks for the completed tasks, were collected. This experimental design allows for the investigation of auditory, visual and audiovisual distraction effects on mathematical calculation, as well as the effect of the distraction on easy and more difficult tasks, and lastly, the effect of the different distraction on the mathematical calculations over the span of three days.

If indeed there is a negative effect of the distractions, the reaction times will be higher in the distraction conditions, the participants will not be able to complete as many tasks in the distraction conditions (lower efficiency), and the number of correct answers will be fewer in the distraction conditions (lower accuracy), compared to the control condition. If visual distraction has a larger negative effect on the easy mathematical tasks, the reaction times will be higher, and the efficiency and accuracy will be lower for the easy tasks, compared to the difficult tasks. If there is a learning effect for visual distraction over time, the reaction times will get lower, and the efficiency and accuracy scores higher in the visual condition compared to the other distraction conditions, and the control condition.

The current study advances previous research because the design combinates modality, difficult, and a three-day time span. Furthermore, the study includes audiovisual distraction, which no previous studies have investigated. The design of the study makes it possible to test the presented hypotheses, however, the study can also potentially observe whether there are differences between the easy and the difficult tasks for the visual distraction in terms of the training effect, compared to the training effect for the easy and difficult tasks in the control condition, the auditory condition, and the audiovisual condition.

## Participants

The study included data from 27 of 30 participants who completed the experiment. The collected data from three participants were excluded due to technical issues in the middle of trial. This meant that these three participants had to start the trial they were on from the beginning and therefore complete math tasks that they had already completed once. Of the 27 participants included, 7 were male (26%), and 20 were female (74%). The age of the participants ranged from 18 to 28, with a mean of 23.0 (*SD* = 2.93). All the participants in the study were students at the Norwegian University of Science and Technology (NTNU), and were recruited at the Dragvoll campus.

Participants were recruited in different lectures at the campus. Because of the ongoing corona pandemic, both physical and digital lectures were attended. The students were informed about what the purpose of the study was, what participation would involve for them, and that everyone who participated in the project would receive a small compensation. They were also told that everyone who participated in the study would have a chance of winning one of six gift cards. The students that were interested in participating in the study was instructed to go on to a website and answer a short recruitment survey.

The recruitment survey was constructed using a website developed by the University of Oslo (UiO; https://www.nettskjema.no/user). The recruitment survey informed the participants further about the study, that participation was completely voluntary, and that collected information about them would be handled anonymously. The only inclusion criteria for participating in the study was the age range (18 to 28 years), and that the participants were students at NTNU with normal hearing and normal/corrected to normal vision. The first three of the questions in the recruitment survey therefore asked the participants to confirm this. A fourth and last question asked the participants to leave their contact information (either a phone number or an e-mail address) so they could be contacted regarding the experimentation.

On the first day of the experiment the participants answered a handedness questionnaire (Oldfield, 1971; see Appendix C for the handedness questionnaire) and completed the Ishihara test for colour blindness (Ishihara, 1974). However, this information was not used as inclusion criteria for participating in the experiment. This information was collected as control criteria. On the first day the participants also answered a questionnaire asking about their gender, their age, their experiences with mathematical calculations, and whether or not they had a medical condition or took medication that could affect calculation, hearing and/or vision. The questionnaire also asked about their general health that day and how rested they felt that day (see Appendix B for the background questionnaire). A shorter version of this questionnaire was completed the next two days, which only included the questions asking for use of medication that day, their general health that day and how rested they felt that day. All participants read and signed the project consent form (see Appendix A for the consent form). An application for det project was submitted to and approved by the Norwegian Centre for Research Data (Norsk senter for forskningsdata; NSD).

## Materials

The task stimuli in this experiment are mathematical addition tasks and mathematical subtraction tasks. Furthermore, both the addition tasks and the subtraction tasks will either be classified as easy or classified as difficult. The distraction stimuli in this experiment are either auditory, visual, or audiovisual. The visual distraction are coloured circles and the auditory distraction is a short metallic sound.

### *Mathematical tasks*

Two sets of math tasks were developed. One set of tasks would be relatively easy for adult university students, and one set of tasks would be slightly more difficult. Rules were developed to systematically differentiate between easy and difficult mathematical tasks. Both the easy and the difficult math tasks consist of addition and subtraction tasks. Furthermore, both the easy and the difficult math tasks consist of only two numbers to be either added together or subtracted from each other. The numbers in both the easy and the difficult tasks have a range between the values of 11 to 88 (11 to 99 for the subtraction tasks), such that the correct answer to both the easy and difficult tasks also consist of only two digits. Furthermore, none of the numbers to be added or subtracted can contain the value 0, excluding the numbers of 20, 30, 40, 50, 60, 70, 80, and 90 from the range. The correct answers to the easy and difficult tasks cannot contain the value 0.

Working memory has been shown to play an important role for mathematical cognition (Ashcraft & Krause, 2007). However, larger working memory load is found to negatively impact multidigit addition tasks where one must carry over, to a larger extent, than multidigit addition tasks where one must not carry over (Kalaman & LeFevre, 2007). This may also be relevant for the subtraction tasks, where one has to borrow to find the correct answer to the task. This has been taken into account when creating the rules for the math tasks. Example tasks and rules for the easy and difficult addition tasks, and the easy and difficult subtraction tasks are presented below.

**Example and rules for an easy addition task:** Example: 32 + 14 = 46.

1. The participant can find the correct answer by adding the first digits of the numbers together and the second digits of the numbers together, without exceeding 9.
    a. The participant will not need to carry over any digits to find the correct answer
    b. In the example above, one can simply add 1 to 3 and 4 to 2 to find the answer.
2. The number with the lowest value must be presented last.
    a. In the example over, the number 14 is presented after the number 32.

**Example and rules for a difficult addition task**. Example: 36 + 48 = 84.

1. The participants cannot find the correct answer by adding the first digits of the numbers and the last digits of the numbers together, without exceeding 9.
    a. This means the participant must carry over to find the correct answer.
    b. In the presented example the answer is NOT given as the sum of the first digits of the numbers, and the sum of the last digits of the numbers.
2. The number with the lowest value must be presented first.
    a. In the example above, the number 48 is presented after the number 36.

**Example and rules for an easy subtraction task.** Example: 48 – 22 = 26.

1. The correct answer cannot have a value below 0.
    a. The number with the lowest value is presented last
    b. In the example, the number 22 is presented after the number 48.
2. One can find the correct answer by subtracting the first digits and the second digits of the two numbers, without getting a value less than 1.
    a. The participant will not have to borrow any digits to find the correct answer
    b. Using the same example, one can see that the participant can find the correct answer to the task by subtracting 2 from 4 and by subtracting 2 from 8.

**Example and rules for a difficult subtraction task.** Example: 57 – 39 = 18.

1. The correct answer cannot have a value below 0.
    a. The number with the lowest value is presented last
    b. In the example, the number 39 is presented after the number 57.
2. One cannot find the correct answer by subtracting the first digits and the second digits of the two numbers, without getting a value less than 1.
    a. The participants must carry digits over to find the correct answer.
    b. In the presented example, the answer is NOT given by subtracting the first digits of the numbers, and by subtracting the last digits of the numbers.

Using the rules presented above, possible math tasks and their correct answers were written down in Microsoft Excel. For the easy addition tasks, for example, 14 was added to every possible number between 11 and 85 (taking away every task that broke the rules). In the same way, 25 or 32 (e.g.), were added to every possible number between 11 to 74 or 11 to 67, respectively. Any duplicates were excluded. When choosing a math task to be included in one of the experimental conditions, both the chosen task and the possibly repeating task was removed from the Excel file. The tasks to be included in the experiment were randomly chosen. The same procedure was used to choose the difficult addition tasks, the easy subtraction task, and the difficult subtraction tasks (always following the rules). For every condition of the experiment, 30 easy math tasks and 26 difficult math tasks were chosen. The 30 easy tasks consisted of 15 addition tasks and 15 subtraction tasks. The 26 difficult tasks consisted of 13 addition tasks and 13 subtraction tasks. A larger number of easy math tasks were chosen because it was expected that the participants would manage to complete more easy tasks than difficult tasks within the two minutes. Within the easy tasks and the difficult tasks, the addition and subtraction tasks were completely randomized.

There was prepared three different versions of the experiment; with completely different tasks for the three days. This was to make sure that the participants did not receive the same math tasks across the three days of doing the experiment. Said in a different way, there were no similar tasks, neither within one version of the experiment, nor across the three versions of the experiment. One version of the experiment had a set of easy and difficult tasks for each of the four conditions. This means that one version of the experiment had 224 tasks. With the three versions of the experiment, this makes 672 different tasks. The three different versions of the experiment were given in randomized order. This means that one of the participants would, for example, receive version two of the experiment on day one, version three on day two, and version one on day three. Another participant would for example receive version one on day one, version three on day two, and version two on day three.

Six different versions of the experiment were made based on what order the different conditions would appear in, and in regards to whether the easy or difficult tasks would appear first or last within one condition. Every participant would receive the control condition first, where the easy tasks (E) came before the difficult tasks (D), each day of doing the experiment. In version 1 of the experiment the order of the other conditions would be auditory (DE), visual (ED), and audiovisual (DE). For version 2 the order would be visual (DE), auditory (ED), and audiovisual (ED). For version 3 it would be visual (ED), audiovisual (DE), and auditory (ED). For version 4 it would be audiovisual (ED), visual (DE), and auditory (DE). For version 5 it would be audiovisual (DE), auditory (DE), and visual (ED). Auditory (ED), audiovisual (ED), and visual (DE) would be the order for version 6. The participants were randomly given one of the versions each of the three days.

### ***Distraction stimuli***

The distraction stimuli in the experiment appear suddenly and last for a short period of time, followed by a period of no distraction. The experimental conditions are visual distraction only, auditory distraction only and audiovisual distraction. There is also a control condition with no distraction. The auditory and visual distraction stimuli were made with the program MATLAB R2021a, using an existing code. The base code was developed for the Speech Lab to be used in a distraction experiment. The distraction experiment was conducted as part of two master's theses in psychology (see Høgh, 2021; Wilhelmsen, 2021). The MATLAB code creates short videos of the distraction stimuli. The visual distraction was coded to be red, blue and yellow circles that pop up at random locations on the computer screen, within a given area around the math task. The border of the circles was coded to have a grey color. What color (blue, red or yellow) to pop up was coded to be randomized.

Some changes were done to the existing MATLAB code, however. The circles were made bigger, resulting in a diameter of 5 cm, and coded to have a shorter duration. Furthermore, the time interval between the auditory and visual distraction onset was coded to vary more, since stimuli that vary more and are more unpredictable is considered more distracting (Schlittmeier et al., 2008; Parmentier et al., 2011). No changes were made to the color of the circles and the border colour. The randomization of colours was also preserved. A different sound file was used in the code; a metallic clanking sound replaced a softer thudding sound. The metallic sound was downloaded free from a website called ZapSplat (https://www.zapsplat.com). For the audio file to be able to fit in the existing code, it had to be in m4a-format, the short sound had to be repeated to create an audio clip with a duration of two minutes, and the frequency had to be reduced from 48000 hz to 44100 hz. This was done using the program Audacity 3.0.4. Lastly, the sound had a peak amplitude of 12 db.

The videos MATLAB created consisted of 30 frames per second, which makes 900 frames for the whole video of 30 seconds. With the changes to the code, the auditory and visual distraction stimuli would show up for five frames (0.2 seconds), and the blank period would vary between five frames (0.2 seconds) and 25 frames (0.8 seconds). In the audiovisual distraction condition, the auditory and visual distraction stimuli was coded to be synchronized. Every time a circle would appear on the screen, the sound would appear simultaneously, and both stimuli would have the same duration. For example, a circle and the sound would appear for 0.2 seconds and then there would be a blank period for 0.6 seconds before a new circle and sound would appear for 0.2 seconds.

To be able to use the video files from MATLAB in the experiment, the files had to be compromised. That is, the files were too big to be manageable (each file having a size of 2.6 GB), and had to be transformed from avi-format to mp4-format. The file compression was done using the program Handbrake 1.5.1. Handbrake compressed the size of the files without noticeably reducing the video quality, nor the audio quality. The resulting mp4-files had sizes varying from 70 KB to 500 KB, depending on the distraction condition. Furthermore, the files had a resolution of 1080p HD and a display size of 1120x850 (ratio 4:3).

The experiment was created with SuperLab 6.0. In SuperLab the overarching blocks, the different trials and the events were made. The blocks included one or more trials, and within the trials there were several events. The first blocks of the experiment consisted of the instructions and picture files for the Ishihara test. The next blocks consisted of general instructions for the experiment and specific instructions for the calculations. The next block consisted of four training calculations to make sure the instructions had been understood. The next blocks of the experiment consisted of trials with easy and difficult tasks for each of the four conditions of the experiment. Each trial lasting for 2 minutes. This makes 8 trials lasting a total of 16 minutes. Between every condition there were blocks with video files used for breaks. This means that the experiment had three breaks. The breaks were short video clips of sea animals swimming in the ocean, accompanied by classical music. The second break had a duration of one minute, while the first and third brake lasted for 30 seconds each.

### ***Experimental room and equipment measurements***

The room where the experiment took place was neutral and silent with white walls and white roof. The room did not have any windows. In the room there was set up four computers; each computer placed on identical desks with identical chairs placed in front of the desks. The chairs had four legs to prevent the participants from moving around and adjusting their distance to the computer screens during the experiment. Neutral partition walls were used to separate the four different setups. With these setups, every participant would be facing a white wall while doing the experiment, and would not be easily distracted by other participants. The computers used for the experiment were stationary iMacs installed with macOS Sierra 10.12.6 or newer. All the iMacs were 27 inches, and had a 5K resolution (5120 x 2880 pixels). Headphones, the computer keyboards, and the computer mouses were connected to the computers. The computer mouses, however, was only operated by the experimenter. The computer keyboards were standard numeric keypads (numbers both on top and on the right side), and was 43 cm long and 11.5 cm wide. The headphones used were AKG K273 ear enclosing, stereo closed, and dynamic studio headphones of 68±1 dBA.

The height of the desks used were 71,5 cm. The distance between the nearest part of the computer foot and the edge of the desk was 46,5 cm. The distance from the computer screen to the back of the chair was 102,5 cm, and the distance between the nearest part of the computer foot and the back of the chair was 97,5 cm. The distance from the nearest part of the computer keyboard to the edge of the desk was 6,5 cm. Both the computer, the computer keyboard and the chair were placed centred relative to the desks. There were markings on the floor for where the chair was supposed to be placed during the experimentation. The distance from the floor to the chair seat was 44 cm. It was made sure that the computer screen was set at a 90-degree angle relative to the desk. To make sure that the participants only used the numbers on the top of the keyboard, the numbers on the side were covered with paper. The participants were allowed to use both hands to give their answers. The brightness of the computer screen was set to 8 out of 10, and the volume was set to 4 out of 10. The participants were asked to not change the brightness or the volume. None of the participants adjusted the chair, the desk or the keyboards. Furthermore, none of the participants changed the computers volume- and brightness-settings.

## Procedure

The participants were greeted outside of lecture hall D15 at NTNU Campus Dragvoll. The participants were then taken down to the Perception Lab at the Institute for Psychology, where the experimentation would take place. The participants were seated in front of the computer assigned to them, with the computer keyboard, the headphones, the computer mouse, the consent form, and a pen available on the desk. After giving their consent, the participants were asked to complete the handedness questionnaire and the background questionnaire. These two questionnaires were also given in paper form.

When the participants had completed the questionnaires, they were asked to do the Ishihara test for colour-blindness. This test was done using the computer. Instructions for the test was given on the computer screen. The participants were told they would be presented with several coloured circles and to type the number they see inside the circle using the computer keyboard. The participants confirmed with the enter button. The pictures of the coloured circles would show up in randomized order. After pressing the enter button, the next picture would immediately show up. The participants received instructions that the test was over when they had given all five answers, and told to wait for further instructions. The Ishihara test was passed if the participant gave five out of five correct answers. There was no time limit for completing the Ishihara test, and no time limit for the participants to give the individual answers.

The participants would now be told that the mathematical calculations on the computer would begin, and that the calculations would take about 20 minutes to complete. To start the experiment the participants pressed the enter button on the computer keyboard. Instructions were given on the computer screen. General instructions told the participants that they would try to solve several mathematical tasks as precisely and as quickly as possible. More specific instructions on how to answer the tasks were then given. These instructions informed the participant that a series of math tasks would show up on the screen, and that for each task they would use the keyboard to type down their answer, and then confirm their answer by pressing the enter button. Once more, the participants were reminded to answer as precisely and as quickly as possible. The participants were then given four training tasks to make sure that the instructions had been understood. The training tasks consisted of one easy addition task, one difficult addition task, one easy subtraction task and one difficult subtraction task (in that order). There was no time limit for completing the training tasks.

The structure of the experiment is a series of four-minute streams of math tasks, varying in math task difficulty (easy, difficult) and in distraction (none, auditory, visual, audiovisual), with either a 30 second or 60 second break between streams. There is two minutes of easy tasks and two minutes of difficult tasks. One trial is therefore 2 minutes long. One math task is presented in the middle and lower part of the computer screen. The participants type their answer into a box placed in the middle and at the bottom of the screen (e.g., if the math task is 23 + 22, they type in 45) and then press the enter-button to give their answer. The participants were not able to use any aiding equipment; they had to do the calculations in their heads as quickly as possible. Right after the participants press enter, the next math task is presented. The math tasks stay presented on the screen until the participants give their answer. When the two minutes are up the participants have the opportunity to answer the current task before the next two minutes starts.

In every version of the experiment, the participants will complete two minutes of easy tasks and then two minutes of difficult tasks without any distraction first (this means the control condition is always presented first). Then the participants are given a 30 second break. The distraction conditions to be presented next, and which order the easy and difficult tasks would be in for the different conditions, depends on what version of the experiment the particular participant has been assigned. The second break is 60 seconds and presented after the fourth trial. The third break is 30 seconds and presented after the sixth trial. After the eight trial the experiment is over. If more than one participant did the experiment at the same time, those who would finish first was instructed on the computer screen to sit tight and watch a longer video clip of sea life until all the participants were finished.

SuperLab logged the response time and accuracy of each response to a datafile. The collected data were then saved on a memory pen. After completing the experiment, the participants were asked about how the experience was and how they felt about the distraction and the calculations. Anything they said would be noted in a notebook under a headline with the participant code. In total, the participants spent about 40 minutes in the lab the first day. On the second and third day the time spent in the lab was approximately 30 minutes, since the participants did not do the Ishihara test and only completed a shorter version of the background questionnaire. The experiment was structured the exact same way as described above on both day two and day three. For each participant the experiment was conducted at the same exact time on each of the three consecutive days. For example, if one participant did the experiment at 12:15 the first day, the participant did the same experiment at 12:15 the following two days.

The participants sat straight upright in the chair and kept their backs pressed against the back of the chair during the entire experimentation. The participants could end the experiment at any given time if they wanted to. If the participants had any questions or if there were any technical problems, they would raise their hand to get the experimenter's attention. During the entire experiment, the participants kept their headphones on and kept their full attention on the computer screen. In total, the participants would have two minutes of breaks each day of completing the experiment. Any questions the participants had the end of the experimentation were answered.

### *Special procedures related to the pandemic*

Because of the ongoing corona pandemic, extra hygienic precautions had to be taken to reduce the likelihood of contamination. Before testing sessions, the desks, the computer keyboards, the pens, the headphones, the computer mice, and the chairs were thoroughly wiped with an antibacterial cleaning wipe. When arriving at the lab the participants were asked to use an antibacterial agent on their hands. The experimenter did the same. National and local restrictions were followed. During the time of experimentation, participants were not required to use a facial mask, and there was no need to register the date and time of ones stay in the room of the experimentation, but the participants were free do so if they wanted to. If several participants did the experiment at the same time, they were asked to keep at least one meter distance from each other. After completing the experiment and before exciting the room, the participants used an antibacterial agent on their hands once more.

## Results

The collected data were checked for specific tasks that may have been more difficult or easier than others, but no evidence of this was registered. Some of the participants, however, managed to complete all the available tasks within one trial before the two minutes were up, and would solve random tasks from the same calculation set anew. For example, if one participant managed to complete all easy tasks for one trial in one and a half minute, the participant would receive random tasks from the same set for the last 30 seconds. To exclude repeated tasks, the participant with the quickest trial was identified, using the cumulative time. The fastest participant used one minute and 20 seconds to complete all the tasks in one trial. Every trial for every participant was then cut at one minute and 20 seconds, such that each set of tasks was based on the participants performance within this time span.

The collected data were used to create two datasets, in order to look at individual task reaction times, and then percent tasks completed and percent tasks correct. The reaction time dataset therefore included reaction times for each specific math task and whether the answers were correct or not. A shorter datafile was then created, where the percent tasks completed and percent tasks correct was calculated. The percent tasks correct was calculated based on the number of correct tasks for the completed tasks. Both the datafiles included which day the tasks were completed (1, 2 or 3), the modality of the tasks (still, auditory, visual, or audiovisual), and the difficulty of the tasks (easy, or difficult). The shorter file was made for two reasons. Firstly, the participants would not complete the same number of tasks during the experiment, meaning there would be more data available for some of the participants than others. Secondly, to counteract that the easy and difficult tasks had a different number of available tasks (30 for the easy tasks and 26 for the difficult tasks).

Both of the datasets were used to run the analyses, where reaction time and percent task completed were the efficiency measures, and percent tasks correct was the accuracy measure. The dependent variables are therefore reaction time, percent tasks completed and percent tasks correct. There were some data points for reaction time that stood out. For example, some of the participants used close to 30 seconds to respond to one task. However, the data points were not considered to be extreme enough to be treated as outliers. Some data points for percent tasks correct also stood out, where some of the participants had very low scores. However, these scores were not treated as outliers.

A linear mixed model, rather than a repeated measures ANOVA, was chosen for running the three analyses. This choice was made because a mixed model can account for random effects, and thus also account for more of the variance in the data (Smith, 2012). Furthermore, the mixed model can acknowledge individual differences and is more suited for longitudinal data than a repeated measures ANOVA (Krueger & Tian, 2004). The statistical analyses were carried out with JASP 0.16.

## Reaction Time

For the analyses on Reaction Time, the fixed effect variables were Day (1, 2 or 3), Modality (still, auditory, visual, and audiovisual), and Difficulty (easy and difficult), while participant was used as the random effect grouping factor. Model terms were tested with the

Satterthwaite method. Table 1 gives an overview of the statistical results from the linear mixed model.

**Table 1**

*Linear Mixed Model Summary – Reaction Time (ms)*

| Effect | df | *F* | *p* |
|---|---:|---:|---:|
| Day | 2, 8568.34 | 167.932 | < .001 |
| Modality | 3, 8568.14 | 6.927 | < .001 |
| Difficulty | 1, 8568.49 | 2514.922 | < .001 |
| Day ✻ Modality | 6, 8568.12 | 7.709 | < .001 |
| Day ✻ Difficulty | 2, 8568.15 | 17.662 | < .001 |
| Modality ✻ Difficulty | 3, 8568.08 | 15.272 | < .001 |
| Day ✻ Modality ✻ Difficulty | 6, 8568.10 | 1.821 | 0.091 |

The first hypothesis proposed that distraction would have a negative effect on the efficiency of mathematical calculation. A significant main effect difference of Reaction Time for Modality was found, *F*(3, 8568.14) = 6.93, $p < .001$, $\eta^2 = .002$. Surprisingly, a Tukey post hoc analyse revealed significantly longer Reaction Time for the control condition (*M* = 6454, *SD* = 4648) and each of the other modalities: the auditory condition (*M* = 6370, *SD* = 3831), $p < .05$, the visual condition (*M* = 6354, *SD* = 4194), $p < .001$, and the audiovisual condition (*M* = 6287, *SD* = 4344), $p < .05$.

**Figure 1**

*Day x Modality x Difficulty Interaction – Reaction Time (ms)*

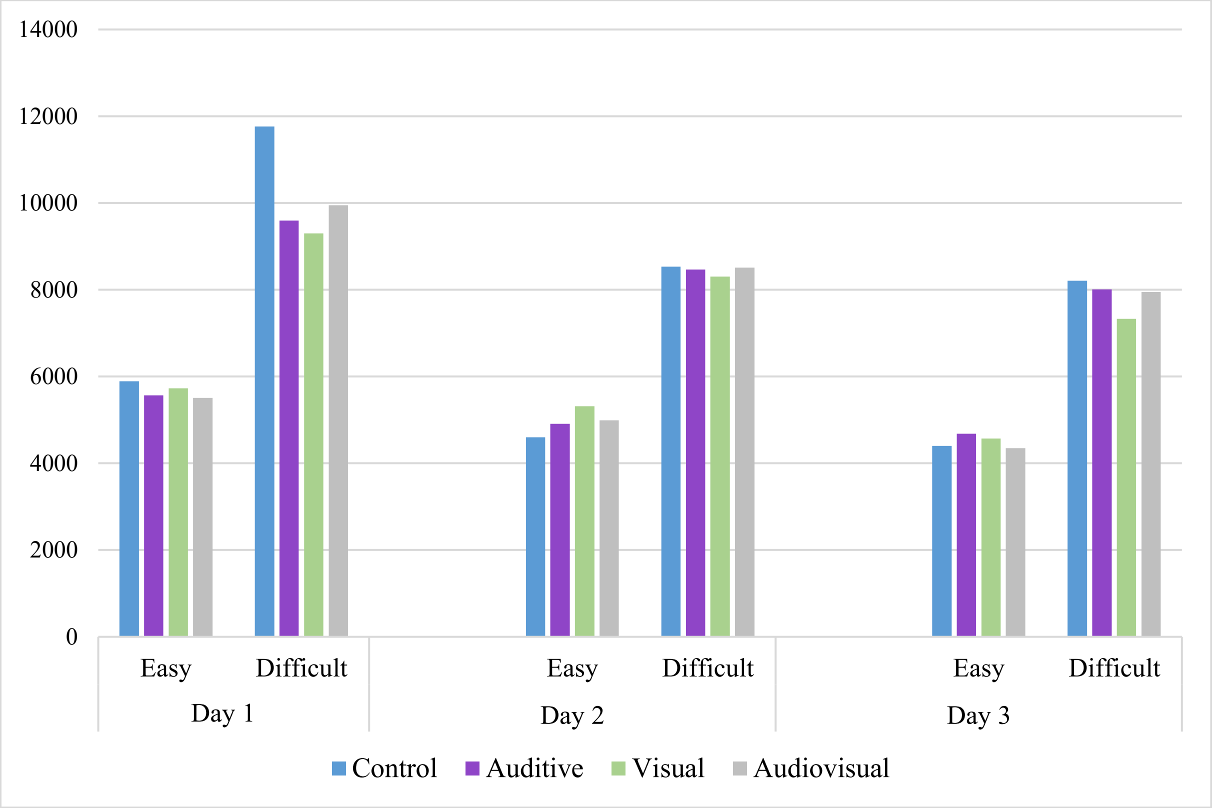


Figure 1 illustrate the interaction of Day, Modality, and Difficulty for Reaction Time. Modality and Day had a significant interaction for Reaction Time, *F*(6, 8568.12) = 7.71, $p < .001$, $\eta^2 = .003$. A Tukey post hoc analyse revealed a significantly higher mean Reaction Time on day 1 for the control condition (*M* = 7967, *SD* = 6301), compared to the other modalities: the auditory condition (*M* = 7067, *SD* = 4104), $p < .001$, the visual condition (*M* = 7122, *SD* = 4210), $p < .001$, and the audiovisual condition (*M* = 7121, *SD* = 4843), $p < .001$. However, no significant mean difference in Reaction Time was found among the different modalities on day 2 and on day 3. The distraction conditions and the control conditions had significantly lower reaction times on day 2 (*M* = 6002, *SD* = 3518 for control; *M* = 6214, *SD* = 3766 for auditory; *M* = 6468, *SD* = 4883 for visual; *M* = 6276, *SD* = 4603 for audiovisual), than on day 1 (*M* = 7967, *SD* = 6301 for control; *M* = 7069, *SD* = 4104 for auditory; *M* = 7122, *SD* = 4210 for visual; *M* = 7121, *SD* = 4843 for audiovisual), where $p < .001$ for control and audiovisual, $p < .01$ for auditory, and $p <. 05$ for visual. The visual condition was the only one to have a significant improvement from day 2 to day 3 (*M* = 5636, *SD* = 3296), $p < .001$.

**Table 2**

*Means for the Modality x Difficulty Interaction – Reaction Time (ms)*

| | Control | Auditory | Visual | Audiovisual |
|---|---|---|---|---|
| Easy | 4885, *2496* | 5024, *2418* | 5164, *3530* | 4906, *3194* |
| Difficult | 9300, *6079* | 8639, *4623* | 8340, *4463* | 8734, *4988* |

*Note*. Standard deviations in cursive.

The means for the Modality and Difficulty interaction is presented in Table 2. Modality and Difficulty had a significant interaction for Reaction Time, $F(3, 8568.08) = 15.27$, $p < .001$, $\eta^2 = .003$. A Tukey post hoc analyse revealed no significant difference in mean Reaction Time for the easy tasks across Modality. However, mean Reaction Time was significantly higher for the difficult tasks in the control condition ($M = 9300$, $SD = 6079$) compared to the other modalities: the visual condition ($M = 8240$, $SD = 4463$), $p < .001$, the auditory condition ($M = 8639$, $SD = 4623$), $p < .001$, and the audiovisual condition ($M = 8734$, $SD = 4988$), $p < .01$. Auditory, visual, and audiovisual distraction had a positive impact on reaction time only for the difficult tasks. Furthermore, the Reaction Rime means for the easy tasks in the distraction conditions were slightly higher than in the control condition, as Table 2 shows. As Figure 1 illustrates, Reaction Time is specifically long for the difficult tasks in the control condition on day 1. On day 2 and day 3, however, Reaction Time is more similar across Modality and Difficulty.

The second hypothesis proposed that the negative effect of visual distraction would be greater for easy tasks than for difficult tasks. As described in the section above, difficult tasks in the control condition had significantly lower Reaction Time than difficult tasks in the other conditions, and no significant difference in Reaction Time was found for easy tasks across Modality. See Table 2 for the means and standard deviations. A significant main effect difference of Reaction Time was found for Difficulty, $F(1, 8568.49) = 2514.92$, $p < .001$, $\eta^2 = .18$, where easy tasks ($M = 4993$, $SD = 2947$) had lower mean Reaction Time than difficult tasks ($M = 8715$, $SD = 5070$).

**Figure 2**

*Day x Modality Interaction, with Standard Deviations – Reaction Time (ms)*

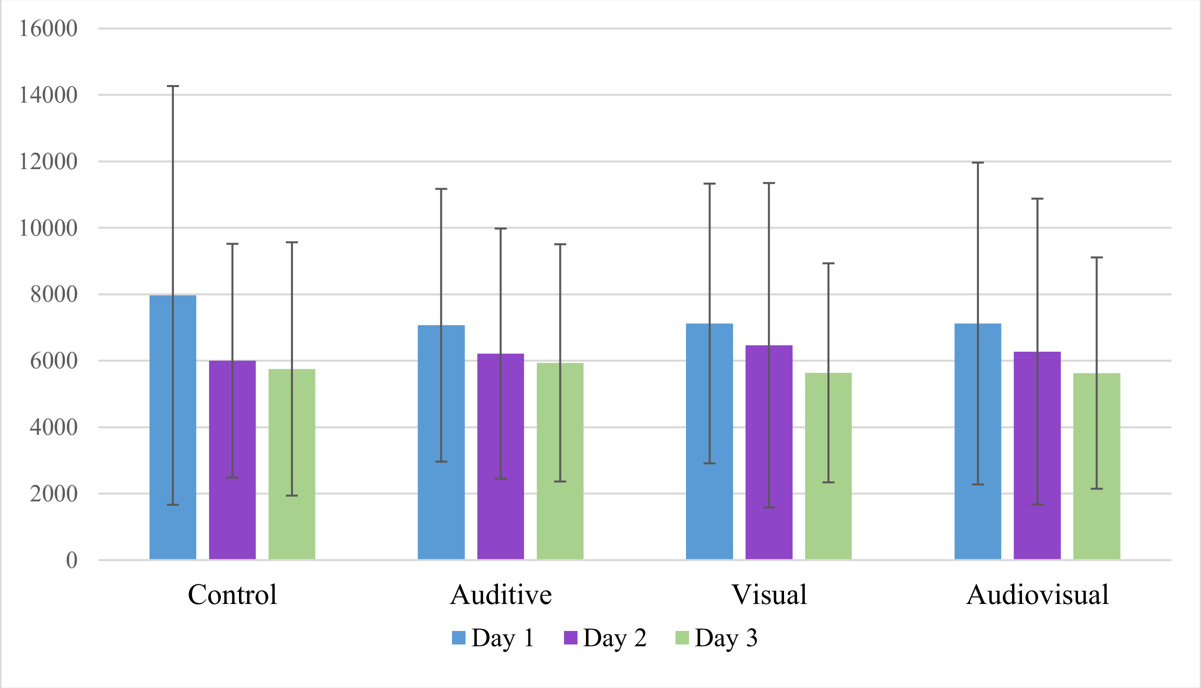


Figure 2 illustrate the interaction of Modality and Day for Reaction Time. The third hypothesis proposed that the negative effect of visual distraction on efficiency was expected to decline in the course of day 1 to day 3. As described above earlier, the control condition had significantly higher mean Reaction Time, compared to the other modalities on day 1, however, no significant difference was found for Modality on day 2 or day 3. Furthermore, all the conditions had a significant improvement from day 1 to day 2, but only the visual condition had a significant improvement from day 2 to day 3.

The control condition had highest mean Reaction Time on day 1, but the lowest on day 2. On day 3 the auditory condition had the highest mean Reaction Time, followed by the control condition, the visual condition, and the audiovisual condition. The control condition had the overall largest improvement in mean Reaction Time, followed by the audiovisual condition, the visual condition, and the auditory condition. The visual distraction had the largest improvement from day 2 to day 3, while the control condition had the smallest improvement from day 2 to day 3. A significant main effect difference in Reaction Time was found for Day, $F(2, 8568{,}34) = 167.93$, $p < .001$, $\eta^2 = .03$. A Tukey post hoc analyse revealed a significantly lower mean Reaction Time for day 1 ($M = 7307$, $SD = 4924$) compared to day 2 ($M = 6238$, $SD = 4226$), $p < .001$, and significantly lower Reaction Time for day 2 compared to day 3 ($M = 5737$, $SD = 3544$), $p < .001$.

Lastly, Day and Difficulty had a significant interaction, $F(2, 8568.15) = 17.66$, $p < .001$, $\eta^2 = .003$. A Tukey post hoc analysis revealed a significantly higher mean Reaction Time for difficult tasks compared to easy tasks for all three days. A significant decrease in reaction time was found for both the easy and difficult tasks from day 1 to day 2, and from day 2 to day 3. The easy tasks had the overall largest decrease in reaction time. This is, however, expected given the significant main effect of both Day and Difficulty.

### Percent Tasks Completed

For the analyses on Percent Tasks Completed, the fixed effect variables were also Day (1, 2, or 3), Modality (still, auditory, visual, and audiovisual), and Difficulty (easy and difficult), while participant was used as the random effect grouping factor. The model terms were tested with Satterthwaite method. An overview of the statistical results from the linear mixed model is presented in Table 3.

**Table 3**

*Linear Mixed Model Summary – Percent Tasks Completed*

| Effect | df | *F* | *p* |
|---|---|---|---|
| Day | 2, 598.00 | 132.738 | < .001 |
| Modality | 3, 598.00 | 0.836 | 0.474 |
| Difficulty | 1, 598.00 | 1122.984 | < .001 |
| Day ✻ Modality | 6, 598.00 | 2.041 | 0.058 |
| Day ✻ Difficulty | 2, 598.00 | 6.190 | 0.002 |
| Modality ✻ Difficulty | 3, 598.00 | 6.200 | < .001 |
| Day ✻ Modality ✻ Difficulty | 6, 598.00 | 0.307 | 0.933 |

As mentioned, the first hypothesis proposed a negative effect of distractions on efficiency. However, no significant main effect difference in Percent Tasks Completed was found across Modality: the control condition ($M = 46$, $SD = 18$), the auditory condition ($M = 46$, $SD = 16$), the visual condition ($M = 47$, $SD = 17$), and the audiovisual condition ($M = 47$, $SD = 18$). Even though Reaction Time had a significant difference for Modality, no difference was found for Percent Tasks Completed.

**Figure 3**

*Day x Modality x Difficulty Interaction – Percent Tasks Completed*

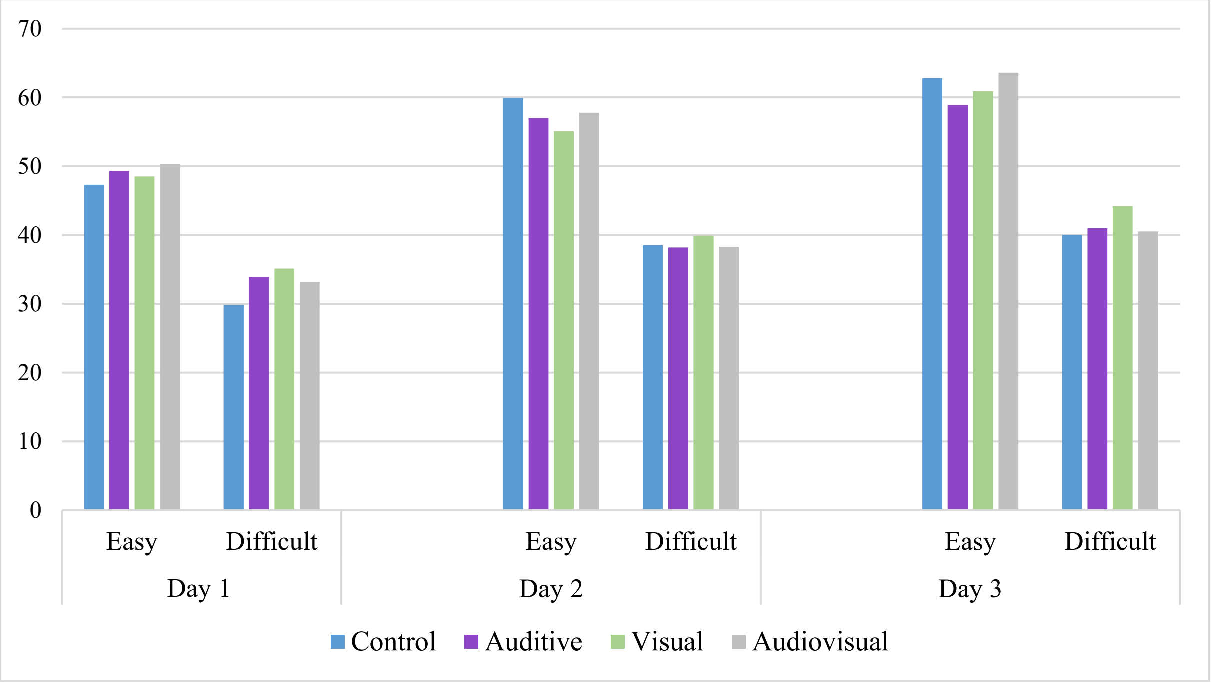


Figure 3 illustrates the interaction of Day, Modality and Difficulty for Percent Tasks Completed. Unexpected, only nearly a significant Modality and Day interaction was found, $F(6, 598.00) = 2.04$, $p = 0.058$, $\eta^2 = .003$. Looking at Figure 3, one can see that on day 1 the control condition had the lowest Percent Tasks Completed for both easy and difficult tasks, the difficult tasks having the lowest mean score, compared to the other modalities. On day 2 the scores for the control condition are best for the easy tasks, and next best for the difficult tasks (beaten by the visual conditions). On day 3, the easy control tasks scored next best and the difficult control tasks scored worst. The pattern on day 2 and day 3 is slightly different from the Reaction Time pattern (see figure 1 for the three-way interaction for Reaction Time).

**Table 4**

*Means for the Modality x Difficulty Interaction – Percent Tasks Completed*

| | Control | Auditory | Visual | Audiovisual |
|---|---|---|---|---|
| Easy | 57, *17* | 55, *16* | 55, *16* | 56, *17* |
| Difficult | 36, *13* | 38, *11* | 40, *13* | 37, *13* |

*Note*. Standard deviations in cursive.

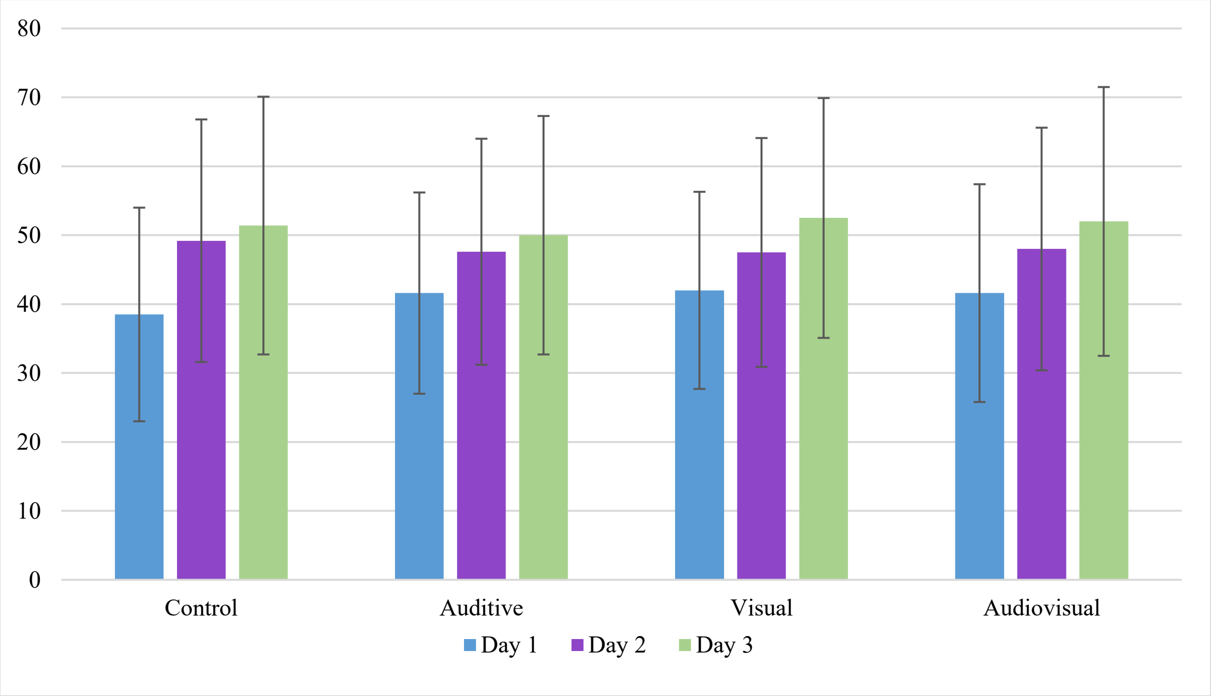
The means for the Modality and Difficulty interaction is presented in Table 4. Modality and Difficulty had a significant interaction for Percent Tasks Completed, *F*(3, 598.00) = 6.20, $p < .001$, $\eta^2 = .004$. A Tukey post hoc analyse revealed a significantly higher mean Percent Tasks Completed for the easy tasks (*M* = 55, *SD* = 16), compared to the difficult tasks (*M* = 40, *SD* = 13), $p < .001$, within the visual condition. A significantly higher mean Percent Tasks Completed was also found for easy tasks (*M* = 56.7, *SD* = 17.0), compared to difficult tasks (*M* = 36.1, *SD* = 12.5), $p < .001$, within the control condition.

The mean Percent Task Completed for the difficult tasks was higher in the visual, auditory, and audiovisual condition than in the control condition. The mean Percent Task Completed for the easy tasks was lower in the visual, auditory, and audiovisual condition, than in the control condition, and the difference in mean Percent Tasks Completed, between the easy and difficult tasks, was smaller in the visual condition than in the control condition. However, the post hoc analysis did not reveal any significant difference in Percent Tasks Completed between the easy tasks in the control condition and the easy tasks in the visual condition, or the other distraction conditions. Nor did the post hoc analysis reveal any significant difference between the difficult tasks in the control condition and the difficult tasks in the visual condition, nor the other distraction conditions. This is different from the Reaction Time results presented earlier.

As mentioned, the second hypothesis proposed that visual distraction would have a greater effect on easy tasks, compared to difficult tasks. As described in the section above, no significant difference in Percent Tasks Completed was found within easy tasks or within difficult tasks, across Modality. A significant main effect difference in mean Percent Tasks Completed was found for Difficulty, *F*(1, 598.00) = 1122.98, $p < .001$, $\eta^2 = .28$, where the mean Percent Tasks Completed was higher for easy tasks (*M* = 56, *SD* = 17), than for difficult tasks (*M* = 38, *SD* = 13).

**Figure 4**

*Day x Modality Interaction, with Standard Deviations – Percent Tasks Completed*



The interaction of Modality and Day for Percent Tasks Completed is presented in Figure 4. Once again, the third hypothesis proposed that the effect of visual distractions on efficiency would decline in the course of day 1 to day 3. As mentioned earlier, no Modality and Day interaction was found for Percent Tasks Completed.

On day 1, the distraction conditions had higher mean Percent Tasks Completed than the control condition. The control condition had the highest mean Percent Tasks Completed score on day 2, compared to the distraction conditions. On day 3, the visual condition had the highest mean Percent Tasks Completed. The control condition had the overall largest increase in Percent Tasks Completed, followed by the visual condition, the audiovisual condition, and lastly the auditory condition. From day 2 to day three, the visual condition had the largest improvement, and the control condition had the lowest improvement. A significant main effect difference in Percent Task Completed was found for Day, $F(2, 598.00) = 132.74$, $p < .001$, $\eta^2 = .07$. A Tukey post hoc analyse revealed a significantly lower mean Percent Task Completed for day 1 ($M = 40.9$, $SD = 15.0$), compared to day 2 ($M = 48.1$, $SD = 16.9$), $p < .001$, and a significantly lower mean Percent Task Completed for day 2, compared to day 3 ($M = 51.5$, $SD = 18.1$), $p < .05$.

Day and Difficulty had a significant interaction for Percent Tasks Completed, *F*(2, 598.00) = 6.19, $p < .01$, $\eta^2 = .003$. A Tukey post hoc analyse revealed a significant difference in mean Percent Tasks Completed between easy end difficult tasks for all three days, where the difficult tasks had lower mean Percent Tasks Completed than the easy tasks. A significant mean increase in Percent Tasks Completed was found for both easy and difficult task from day 1 to day 2, but not from day 2 to day 3. The easy tasks had the highest overall increase in Percent Tasks Completed. This was expected given the significant main effect difference for Day and Difficulty.

### Percent Tasks Correct

For the analyses on Percent Tasks Correct, the fixed effect variables were Day (1, 2 or 3), Modality (still, auditory, visual, and audiovisual), and Difficulty (easy and difficult). Participant was used as the random effect grouping factor, and model terms was tested with Satterthwaite method. An overview of the statistical results for the linear mixed model is presented in Table 5.

**Table 5**

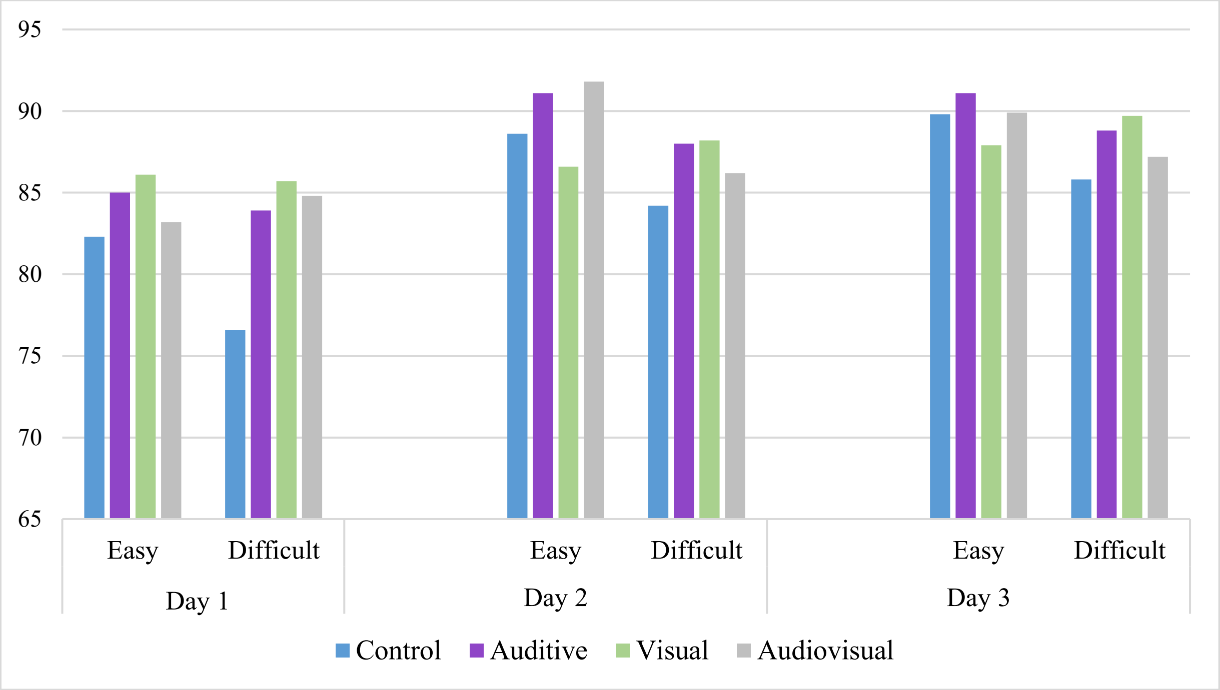
*Linear Mixed Model Summary – Percent Tasks Correct*

| Effect | df | *F* | *p* |
|---|---|---|---|
| Day | 2, 598.00 | 10.955 | < .001 |
| Modality | 3, 598.00 | 2.236 | 0.083 |
| Difficulty | 1, 598.02 | 3.727 | 0.054 |
| Day ✻ Modality | 6, 598.00 | 0.601 | 0.730 |
| Day ✻ Difficulty | 2, 598.02 | 0.207 | 0.813 |
| Modality ✻ Difficulty | 3, 598.02 | 1.440 | 0.230 |
| Day ✻ Modality ✻ Difficulty | 6, 598.02 | 0.360 | 0.904 |

The first hypothesis proposed that distraction would have a negative effect on the accuracy of mathematical calculation. No significant main effect difference in Percent Tasks Correct was found across Modality: the control condition (*M* = 85, *SD* = 18), the auditory condition (*M* = 88, *SD* = 15), the visual condition (*M* = 87, *SD* = 15), and the audiovisual condition (*M* = 87, *SD* = 15). However, the control condition had the lowest mean Percent Tasks Correct, compared to the distraction conditions.

**Figure 5**

*Day x Modality x Difficulty Interaction – Percent Tasks Correct*



Interaction between Day, Modality and Difficulty for Percent Tasks Correct is presented in Figure 5. Modality and Day had no significant interaction for Percent Tasks Correct, *F*(6, 598.00) = 0.60, *p* = .730. Looking at Figure 5, one sees that the Percent Tasks Correct was lowest for the control condition on day 1, compared to the other conditions, where the difficult task specifically had lowest mean scores. Almost the same pattern continues on day 2 and day 3, however the easy tasks for the visual condition on day 2 and day 3 have a lower score than the easy tasks for the control condition on day 2 and day 3.

**Table 6**

*Means for the Modality x Difficulty Interaction – Percent Tasks Correct*

| | Control | Auditory | Visual | Audiovisual |
|---|---|---|---|---|
| Easy | 86, *17* | 89, *12* | 87, *13* | 88, *12* |
| Difficult | 82, *20* | 87, *17* | 88, *17* | 86, *18* |

*Note*. Standard deviations in cursive.

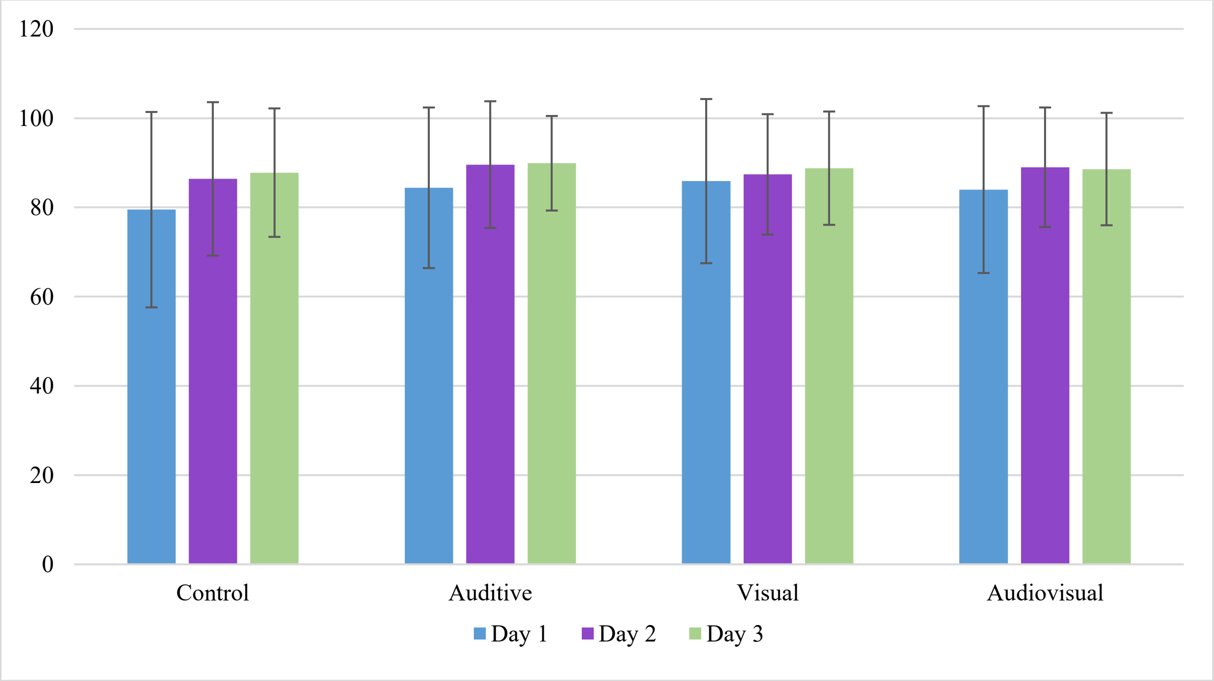
The means for the interaction of Day and Difficulty are presented in table 6. Modality and Difficulty had no significant interaction for Percent Tasks Completed, *F*(3, 598.02) =

1.44, *p* = .230. However, the means reveal that mean Percent Tasks Correct in the visual condition was a little higher for the difficult tasks (*M* = 88, *SD* = 17), than for the easy tasks (*M* = 87, *SD* = 13). However, given the standard deviations, the difference is irrelevant. In the control condition, the easy tasks (*M* = 87, *SD* = 17) had higher mean Percent Tasks Correct than the difficult tasks (*M* = 82, *SD* = 20). The distraction conditions had higher means than the control condition for both the easy and difficult tasks.

The second hypothesis proposed that the negative effect of visual distraction on accuracy would be greater for the easy tasks, compared to the difficult tasks. As mentioned in the section above, no significant interaction of Modality and Difficulty was found for Percent Tasks Correct. Furthermore, no significant main effect difference in Percent Tasks Correct was found between easy tasks (*M* = 88, *SD* = 14) and difficult tasks (*M* = 86, *SD* = 18), but the values were close to being significant, *F*(1, 598,02) = 3.73, *p* = .054. The Percent Tasks Correct was therefore slightly higher for the easy tasks than the difficult tasks.

**Figure 6**

*Modality x Day Interaction, with Standard Deviations – Percent Tasks Correct*



The means for the Modality and Day interaction is presented in Figure 6. The third hypothesis proposed that the negative effect of visual distraction on accuracy would decline over the course of day 1 to day 3. However, as mentioned above, no significant interaction was found for Modality and Day for Percent Tasks Correct. However, a significant main effect difference for Percent Tasks Correct was found for Day, $F(2, 598) = 10.96$, $p < .001$, $\eta^2 = .02$. A Tukey post hoc analysis revealed a significantly lower mean Percent Tasks Correct for day 1 ($M = 83$, $SD = 19$) compared to day 2 ($M = 88$, $SD = 15$), $p < .01$, but no significant difference in Percent Tasks Correct between day 2 and day 3 ($M = 89$, $SD = 13$). Furthermore, for all of the three days, the control condition had the lowest percent tasks correct compared to the other distraction conditions. This was unexpected. All the conditions had the largest increase in percent tasks correct from day 1 to day 2. The control condition had the overall largest increase, followed by the auditory condition, the audiovisual condition, and the visual condition.

## Discussion

The aim of the current study was to investigate the effect of auditory, visual, and audiovisual distraction on the efficiency and accuracy of both easier and more difficult mathematical calculation tasks, over the span of three consecutive days. In the discussion, the dependent variable percent tasks completed translates to efficiency, and the dependent variable percent tasks correct translates to accuracy. Reaction time is an efficiency measure, but the term ‘reaction time’ will be used. Reaction time and efficiency gives insight into the distractor effect of working memory speed, while accuracy gives insight into the distractor effect on working memory precision. The dependent variables are further discussed later in the discussion.

A negative impact of both auditory and visual distraction on efficiency and accuracy was predicted, based on previous research (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013). Surprisingly, the analyses of the collected data indicated that neither the auditory, the visual, nor the audiovisual distraction had a negative impact on the mathematical calculation tasks. The experimental distraction conditions in the study actually showed lower reaction times, higher efficiency, and higher accuracy than the control condition. Furthermore, the easy tasks had lower reaction times, higher efficiency and higher accuracy in all the conditions, compared to the difficult tasks.

Another prediction was that visual distraction would have greater negative impact on the easy tasks than on the difficult tasks, based on the perceptual load model and studies that have found evidence to support the perceptual load model for visual stimuli (Forster & Lavie, 2008; Lavie, 1995; Lavie 2005; Tellinghuisen & Nowak, 2003). The results gave some support to this prediction. The results indicate that the difficult tasks in the control condition had significantly higher reaction times, than the difficult tasks in the other distraction conditions. The difference in reaction times and efficiency were largest between the control condition and the visual condition. No significant difference was found between the easy tasks for the different modalities. However, the means show that the reaction times were higher, and the efficiency lower for the easy tasks in the distraction conditions, compared to the easy tasks in the control condition. The difficult tasks in the control condition had the highest mean reaction time, lowest mean efficiency and lowest mean accuracy. However, the differences between the control condition and the other distraction conditions got more even on day 2 and day 3. This might indicate that distractions might actually be helpful for difficult tasks.

Adaption to visual distraction was predicted to happen over the three consecutive days, based on previous studies that found exactly this for visual distraction on a visual task (Turatto & Pascucci, 2016; Vaina et al., 1995). The current study did find some evidence for this. There was a decrease in reaction times, and an increase in both efficiency and accuracy for the distraction conditions and the control condition over the span of the three days. A larger improvement was registered from day 1 to day 2, than from day 2 to day 3. The control condition had the overall largest improvement in both reaction time, efficiency and accuracy. However, the reaction times and efficiency from day 2 to day 3 were larger for the auditory, visual, and audiovisual conditions, than the control condition. For reaction time, the visual condition was the only condition to have a significant improvement from day 2 to day 3. This might give an indication that some adaptation might have happened, especially since the control condition had the best scores on day 2. The results are discussed below.

## The effect of auditory, visual, and audiovisual distraction

The missing negative effect of auditory, visual, and audiovisual distraction on efficiency and accuracy is not consistent with previous studies (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013). There may be several reasons for the unexpected results. One explanation may be that the majority of the previous studies did not investigate the effect of distraction on mathematical calculation (cf. Heim & Keil., 2019). Some of the studies investigated the effect of distraction on reading and language related tasks (Gao et al., 2012; Klatte et al., 2013), and some studies investigated the effect of distraction on short term memory (Beaman, 2005; Dent, 2010). The operation of solving a mathematical problem in one's head may be different from a task where one merely has to recall either visual stimuli or auditory stimuli. Mathematical tasks are found to demand a lot of working memory capacity (Ashcraft & Krause., 2007). The question of the exact difference between short-term memory and working memory is debatable, and the difference between them may be based on how one defines both short-term memory and working memory (Cowan, 2008). However, the distinction between the two memory functions may be related to the thought that working memory, to a larger degree than short-term memory, processes and manipulates sensory events (Cowan, 2008). Future studies are encouraged to investigate this further.

One can also argue for a difference between language-related tasks and mathematical calculation tasks. Mathematical calculation is thought to involve spatial orientation and visual orientation (Lowrie et al., 2019), while language relies more on the auditory aspects, and on the integration and synchronisation of auditory and visual events (Francisco et al., 2017). The current study included auditory, visual, and audiovisual distraction to be able to see the difference between the modalities. If the effect of distraction on various tasks is related to whether the task is more visual or more auditory, one should expect to see that the visual distraction, but not the auditory distraction, would have a negative impact on rection times, efficiency and accuracy of mathematical calculation. This was, however, not found. The way individuals solve mathematical problems might differ. Some individuals might to a larger extent visualize, and some might rely more on an inner monologue in how they think (Knauff, 2019), and this might have an impact on how one mentally solves mathematical calculation tasks. Furthermore, such individual differences might have an impact on the effects distraction have on mathematical calculations. The variance for the variables in the current study might be an indication of this. However, when one looks at the effect of the distractions on reaction times and efficiency on day two, the performance in the distraction conditions is worse than in the control condition. This might be an indication that the distractions might negatively affect effectiveness of mathematical calculation. This is further discussed below.

It is worth mentioning that the previous study that investigated the effect of distraction on mathematical calculation used a different design than the current study (see Heim & Keil, 2019). In the previous study, the participants would be presented three tasks in a row (only one at a time) for a short period of time, while simultaneously being exposed to the auditory distraction. After exposure to the distraction, the students were to write down the three answers. Furthermore, the tasks included two numbers with only one digit (Heim & Keil, 2019). This difference from the current study might explain the different results. The task in the previous study might be more strongly related to short term memory, than working memory, since the tasks had to be easy enough to solve on a short period of time, and since the answers had to be memorized and recalled a short period after.

Another possible reason for the unexpected results may be related to the nature of the distractions, or the combination of distraction and the task to be performed. One of the previous studies found that visual distraction had a negative impact on short term memory for color, but not for spatial location (Dent, 2010). This suggests that the combination of task and distraction stimuli may be very specific. Furthermore, most previous studies investigated the effect of visual distraction on a visual task, or an auditory distraction on an auditory task. Only two previous studies investigated the cross-modal impact of auditory distraction on a visual task (see Heim & Keil, 2019; Tellinghuisen & Nowak, 2003). Whereas Tellinghuisen and Nowak (2003) found no evidence of auditory distraction having a negative impact on a visual search task, Heim and Keil (2019) found that background noise negatively impacted mathematical calculation, in particular for sounds which were most emotionally engaging. This brings us to the next possible explanation for the unexpected results.

The missing negative effect of distraction might be related to the distractions not being distracting enough. Since previous theories and studies proclaim that unexpected stimuli demand more attention, and therefore will be more distracting (Parmentier et al., 2011; Schlittmeier et al., 2008 Vilares & Kording, 2011), the current study made the visual distractions bigger, and both the auditory and visual distraction more variable. When asked about the distraction many of the participants said they found them distracting, especially the auditory distraction, but this did apparently not affect the performances on the mathematical calculations in terms of reaction time, efficiency and accuracy. Maybe the distraction should have been even more prominent and varied even more in the time between onset of stimuli. Furthermore, maybe if the distractions had been more emotionally engaging, they would have been more distracting. The visual stimuli could be a picture of something that will bring out positive emotions, or negative emotions in most people. This could for example be pictures of cute animals or scary animals. In the same way, the auditory distraction could also consist of something that would arise positive or negative emotions in most people, like the sound of someone laughing or of someone arguing. Said in another way, the distraction might have been too irrelevant to the task. On the other side, in terms of ecological validity, the distraction should be something that resonates with a real-world setting, for example the classroom or the workplace.

A previous study that investigated the effect of both auditory and visual distraction on a visual search task, and found a negative effect of visual distraction, used distractions that were relevant to the task at hand (Tellinghuisen & Nowak, 2003). The task at hand dealt with the search for letters. The visual distraction were also letters, and the auditory distraction were a voice pronouncing a letter. Maybe a negative effect of the distraction on both efficiency and accuracy would be found if the visual distraction were random numbers showing up on the screen, and the auditory distraction was a voice reading different numbers out loud. On the other side, a study using the same experimental setup with an irrelevant visual distraction stimulus found evidence that an irrelevant distraction also could have a negative impact on the performance of the visual search task (Forster & Lavie, 2008). However, the irrelevant distraction was a cartoon character that might arise some emotions in the participants, which could contribute paying more attention to the distraction.

A fourth explanation for the unexpected results might be related to differences between the participants in previous studies and participants in the current study. One of the previous studies found that children were more prone to distraction than young adults (Klatte et al., 2013), and another previous study found that elderly people might be more prone to less severe distraction than younger adults (Gao et al., 2012). Young adults might therefore be more resistant to distraction compared to children and older adults. Many of the previous studies were completed several years ago, so the young adults today might be even more used to dealing with distraction than young adults were earlier. For example, with the increasing use of mobile phones and social media, young adults may indirectly be trained to multitask. Some argue that multitasking might be negative for productivity, whilst others argue for a positive impact of multitasking on productivity (Cardoso-Leite et al., 2015). A meta-analysis investigating distraction found that mobile phone use impacted student's educational outcomes negatively (Kates et al., 2018), however.

Worth mentioning is that multitasking in everyday life might be different from multitasking in research settings in the lab. In addition to finding that media multitasking was distracting for young adults, this previous study also found evidence to support that media multitasking did not transfer to laboratory multitasking (Moisala et al., 2016). Future studies might want to investigate the adaptation to different distraction stimuli for children, younger adults and older adults. Furthermore, future studies might also want to look further into the effects of media multitasking.

A fifth possible reason for the missing negative impact of distraction might be related to the way the experiment was organized in the current study. For every day the participants completed the experiment, and for every version of the experiment, the control condition would always be presented first. This was done to avoid creating too many versions of the experiment. However, this might explain why reaction times were lower, efficiency higher, and accuracy higher in the distraction conditions, than the control condition. The students might have gotten enough practice with the control condition, such that they were better prepared for the other distraction conditions. They might have expected distraction to appear after the break, and in that way been more prepared to deal with them.

Some of the participants found the distractions stimulating to the degree that they felt it helped them to stay focused on the task at hand. Given the results of the current study, where distractions had a positive effect on reaction time, efficiency, and accuracy, the participants might have been more concentrated during the calculations with the distraction than without the distractions. And this might be especially true for the difficult tasks, compared to the easy tasks. In the perceptual load model and supporting research (see Forster & Lavie, 2008; Lavie, 1995; Lavie 2005; Tellinghuisen & Nowak, 2003), tasks with higher difficulty are less prone to a negative effect of distraction. In the current study, instead of treating the distractions as distracting, the participants might unintentionally have used them to occupy their mind, such that no space is available for other possible internal or external distractions. And this might have led to better performance.

Some of the participants actually found it more difficult to do the calculations when the background was white and when there was no sound. Individuals with attention deficit hyperactivity disorder (ADHD) struggle with attending to important information, which might impair performance on certain tasks (van Mourik et al., 2007). This previous study, however, compared children with ADHD and children without ADHD, and found that auditory distraction actually could improve performance on a visual reaction time task for children with ADHD (van Mourik et al., 2007). Whether results like this, in other circumstances, also would apply to individuals that do not have ADHD is unknown, but future research could look further into this. The questionnaire for the current study asked whether the participants had medical history that could negatively impact calculation. A significant difference between the participants that did have a medical history, and the participants that did not have a medical history, where those with a medical history scored significantly higher in reaction time, lower in efficiency and lower in accuracy than the participants with no medical history. The question on the questionnaire was very general, such that other patterns could be found if one investigates this in more detail.

### Distraction and difficulty of mathematical calculations

In the current study, reaction times were significantly lower for the difficult tasks in the distraction conditions, than in the control condition, whereas for the easy tasks, reaction time was similar across the versions of distraction and the control condition. However, the means did reveal that the scores were slightly higher for the easy tasks in the experimental distraction conditions, than in the control condition. The means also revealed the same pattern for easy and difficult tasks on the efficiency scores; however, these tendencies were not significant, and the pattern was not found for easy and difficult tasks on the accuracy scores. This gives some evidence to support the hypothesis that visual distraction would have a smaller effect on the difficult tasks than the easy tasks, but the results are only in part consistent with the perceptual load model (Lavie, 1995; Lavie, 2005), and with previous studies getting evidence to support the perceptual load model where visual distraction only had a negative impact on easy tasks and not difficult tasks (Forster & Lavie, 2008; Tellinghuisen & Nowak, 2003). There results of the current study is partly unexpected, and there might be several reasons for this.

Firstly, because there were no main effect results where the distraction had a negative impact on the mathematical calculation, it would be difficult to capture whether there was a difference in the effect the distraction had on the easy and difficult tasks. Especially since the reaction times were lower and efficiency scores higher in the distraction conditions, than in the control condition. However, when one looks at the modality and day interaction, and the modality and difficulty interaction, there was a pattern where the difficult tasks for the control condition seemed to be the most challenging for the participants on day 1. Furthermore, this changed on day two and day three, such that all the conditions became more similar. At the same time, the control condition had the overall largest decrease in reaction time and increase in efficiency, but this was even larger for the difficult tasks than the easy tasks. This might be an indication that distractions actually can have a positive impact on mathematical calculation, especially for tasks with higher difficulty. Future research might look even further into these findings.

A second explanation for the unexpected distraction effect on easy and difficult tasks, might be directly related to the results regarding the difference in reaction time and efficiency between the easy and difficult tasks. Difficult mathematical tasks seem to demand more capacity of working memory than easy mathematical tasks, as a previous study also found evidence for (Kalaman & LeFevre, 2007). If difficult tasks demand more capacity from working memory, but not all available capacity, capacity may still accommodate attending to distractions. Small distractions might be enough to negatively impact on the reaction times, the efficiency and the accuracy of the calculations. If the difficult tasks had been even more difficult, there might have been less capacity to process the distraction, and the perceptual load effect might have been more prominent. This explanation might also go hand in hand with the distractions in the experiment having nothing to do with the task at hand.

A third possible explanation for the unexpected distraction effect on easy and difficult tasks might be based in the degree of interconnectivity between the task and the distractor, possibly leading to differences in results between the current study, and previous studies that investigated the effect of distraction on easy and difficult tasks. A coherent interpretation of the outside world is created when sensory events are bound together based on their attributes (Schwartz et al., 2012). This principle is important for multisensory perception (Chen & Spence, 2017). Sensory events might have several different attributes, and it is more likely that sensory events will be bound together the more attributes they have (Chen & Spence, 2017; Radvansky & Zacks, 2011). Previous studies (see Forster & Lavie, 2008; Tellinghuisen & Nowak, 2003) differentiated between easy and difficult search tasks by changing which letters that were presented with the target letter. This means that the distraction was a part of the main visual search task as well as being intended to distract the participants. In the current study, the distractions were not related to the task at hand in any way, given that the visual distraction was coloured circles and the auditory distraction a short metallic sound. This means that, in the current study, the differentiation between difficult and easy tasks were based solely on the task to be solved. Speculating, the distractors may have had a greater negative impact on the mathematical tasks, if they had been more interconnected. For example, a mathematical task with several possible answers to choose from. Then the differentiation between the easy and difficult tasks would be based on the correct answer options. Furthermore, as discussed earlier, the difference between a mathematical calculation task and a visual search task might tap into different cognitive functions. The combinations of distractors and the tasks at hand might play a significant role for the experimental results.

A fourth explanation for the unexpected results might be connected to the issue with the repeating tasks in the experiment. However, this is not likely to be the case. Since the data set had to be cut for each participant, some of the collected data was lost. If the current study had been able to include all the data collected within the two minutes for each trial, it could be argued that potential differences across day, modality and difficulty would be more prominent. However, the possible adaptation to the distractions would most likely happen toward the end of the 2-minute trials. Furthermore, doing mathematical calculations with distraction over a longer period of time may be tiresome for the participants. One would therefore have to take into consideration that tiredness could affect the participant’s mathematical calculation performances in a negative way. Thus, keeping the experiment as short as possible could to some extent control for this. The possibility of tiredness was taken into consideration when designing the tasks and the length of the trials. The background questionnaire collected information on the participant's general form each of the three days. A significant correlation was found between general form and accuracy, where a lower general form score actually was correlated with a higher accuracy score. No significant correlation was found for reaction time and efficiency. However, the efficiency score tended to increase with better general form. Future research should try to find a balance between giving the participants enough time with the distraction, and at the same time avoiding the possible negative effect of tiredness.

The previous study that included auditory distraction in the visual search tasks (see Tellinghuisen & Nowak, 2003) found that the auditory distraction actually had a greater negative effect on reaction time and accuracy in the difficult version of the task than in the easy version of the task. This is the opposite of what the current study found for the auditory tasks. In the current study the participants reaction times for the difficult mathematical tasks were significantly lower in the auditory condition than in the control condition, with no significant difference found between the easy tasks in the auditory condition and the control condition. Again, this might be related to the differences in the design of the experiments, both the design of the task and the design of the distraction. However, it also raises the question whether the different sensory systems have their own working memory, as research proposes (Rubin, 2006), or if the sensory systems share the same working memory. It may be that the sensory systems are independent to some degree, but that the specific experimental circumstances might influence the communication between the sensory systems. Further research is needed to investigate this in more detail.

In the perceptual load model, the increase in perceptual load might decrease the processing of irrelevant information, and increase in perceptual load is either an increase in items to be processed, or an increase of attention that the items to be processed demands (Lavie, 1995; Lavie, 2005). While difficult tasks may demand more working memory capacity, and furthermore greater attention, increased attention does not necessarily mean greater working memory load capacity. The functions are closely connected, but the process of attention is arguably the operation of deciding what is to be processed in working memory (Awh et al., 2006). On the other hand, the interaction of attention and working memory may be dependent on what type of attention and what type of working memory an experiment taps into (Awh et al., 2006). The differentiation between attention and working memory might, to some degree, underlie the unexpected results concerning the distractor effects on the easy and difficult calculation tasks.

The results of the current study showed that the easy tasks had significantly lower reaction times, and significantly higher efficiency than the difficult tasks in all the modalities, and across the three days. Furthermore, accuracy tended to be higher for easier tasks than difficult tasks, although the difference did not reach significance, which is an indication that the differentiation between easy and difficult tasks in the current study, using the presented rules, might be credible. The action of carrying over or borrowing in mathematical calculation might demand more working memory capacity than mathematical tasks where one does not have to carry over or borrow. Previous research, specifically on addition, found that having to carry over demands more of working memory, than not having to carry over (Kalaman & LeFevre, 2007). However, this previous study did not include subtraction. The current study therefore strengthens the assumption that borrowing in subtraction also might demand more working memory capacity, than tasks where one does not have to borrow. The current study did not, however, differentiate between addition tasks and subtraction tasks, but had the addition and subtraction tasks in completely randomized order. Having a study investigating addition and subtraction separate could shed further light on whether subtraction task where one has to borrow also demands more working memory capacity. Future research should look more into working memory in relation to mathematical subtraction tasks and addition tasks, separate, and also differentiate between easy and difficult tasks.

## Habituation to auditory and visual distraction

The current study did find some evidence to support the hypothesis that habituation to visual distraction would happen over the span of three days, given that the control condition had the largest improvement in reaction time, efficiency and accuracy over the three consecutive days, compared to the distraction conditions. However, looking more closely into the modality and day interaction for reaction time and accuracy, one might see some pattern to suggest there was some form of adaption to distractions. This will be discussed in more detail below. The results may therefore only to some degree be consistent with previous studies that have found evidence of short-term and long-term habituation to visual distraction (Rozek et al., 2012; Turatto & Pascucci, 2016; Vaina et al., 1995). There might be different reasons for the unexpected results found regarding adaptation to distractions in the current study. These are discussed below.

Firstly, since there was no significant negative effect of the distraction on reaction time, efficiency, and accuracy on day one, it is more difficult to register whether some form of adaptation to the distraction actually happened the next two days. If the distractions showed a negative impact on the calculations on day one, and the scores for the distraction conditions had caught up with the scores in the control condition over the next two days, there would have been a clearer adaptation pattern. The control condition had the highest reaction times, lowest efficiency, and lowest accuracy on day 1, but also had the greatest improvement over the three days. This might be related to the fact that the control condition was presented first for all the participants, and on all of the three days. The improvement in reaction time from day 1 to day 2 for the control condition was almost two seconds, and the efficiency from day 1 to day 2 increased by over ten percent. It might have taken a while for the participants get the hang of the calculations and how to give their answers. On the second day the participants would be more prepared for the calculations and have more experience. This might explain the great performance improvement for the control condition. Worth mentioning, however, is the fact that the participants were given clear instructions for how to give their answers, and this is furthermore reflected in the correct answers given in the four training tasks presented after the instructions.

However, looking into the interaction for modality and day, one can see that the control condition had the largest improvement in reaction time and efficiency from day 1 to day 2, but that the visual distraction condition had the largest improvement in reaction time and efficiency from day 2 to day 3 (and the control condition the smallest improvement from day 2 to day 3). This put together gives an indication that there might have been adaptation to the distractions, especially for the visual distraction condition than the auditive condition and the audiovisual condition. These tendencies are therefore in terms with previous research (Turatto & Pascucci, 2016; Vaina et al., 1995), at least to some extent.

One can ask questions to why the distraction conditions did not have that same improvement from day 1 to day 2, like the control condition. The set order of the trials might be one explanation for this. However, this might also indicate that the distraction had some form of negative impact on the participants performances. If the distraction did not have any impact, one should expect the performances to be the same as the control condition on day 2. However, the reaction times and the efficiency were in fact better for the control condition than the distraction conditions on day 2. Furthermore, the distraction conditions had the greatest improvement in reaction time and efficiency from day 2 to day 3, where the visual condition had the greatest improvement (and the only significant improvement), followed by the audiovisual condition, and lastly the auditory condition. This might show tendencies for an eventual adaptation to the distraction, especially for the visual distraction. Furthermore, the difficult tasks in the control condition seemed to be the most difficult for the participants. This might give an indication that the distractions actually can help the participants perform better on more difficult tasks, as compared to easy tasks. However, further investigation of this is needed to strengthen the claim of adaptation to audiovisual distraction stimuli.

A second explanation for the unexpected results regarding the adaptation to visual distraction over three days, might be related to the differences between the previous studies and the current study. None of the previous studies investigated the effect of distraction on mathematical calculation (see Rozek et al., 2012; Turatto & Pascucci, 2016; Vaina et al., 1995). One study (Turatto & Pascucci, 2016) investigated the participants ability to judge where visual stimuli would appear, and another (Vaina et al., 1995) investigated the participants ability to judge the movement of visual stimuli. The ability to judge the appearance of, or the movement of stimuli might involve different cognitive operations than doing mathematical head calculations. Mathematical calculation might involve working memory (Ashcraft & Krause., 2007) to a larger degree than merely judging appearance or movement of stimuli. Furthermore, the distraction in these two previous studies were related to the task at hand, such that the distraction intended to guide the participants away from the correct answer. One of the previous studies (Rozek et al., 2012) found evidence for short-term habituation to irrelevant visual distraction during reading, but did not investigate long term habituation to the visual distractions.

A third explanation for the unexpected results might be related to the irrelevancy of the distractions. This was discussed earlier in relation to the general effect of distractions on mathematical calculation and in relation to the distractor effect on easy and difficult tasks. The distractions might have been too irrelevant for the calculation tasks that the participants manage to adapt to them very quickly, maybe after just a few seconds of being exposed to them. In one of the previous studies, all of the habituation to the visual stimuli happened within the first day of practice, and lasted the following three days (see Turatto & Pascucci, 2016). Furthermore, passive exposure to coloured circles is found to induce habituation to the stimuli (Won & Geng, 2020). In the current study the participants might have experienced the distractions to be adequately distinct from the calculations, and therefore learnt to ignore them after the first exposure. Some participants found the distractions very distracting, however, this did not have a significant effect on the calculations, based on the overall results across participants. Even though the participant found the stimuli distraction, a subconscious inhibition to them might have happened.

Some participants also reported that the distractions got less distracting over the three days, which might be because of their previous experience with them. If the distraction is considered unimportant, less attention is directed to them (Kandel et al., 2013). The next time the participants are exposed to similar distractors, given no large changes, the irrelevant information might be inhibited. If the distractions were not consistent with previous experience, they would probably demand more attention, and therefore be more distracting (Vilares & Kording, 2011). Future research might look further into the habituation to auditory and visual distraction, as well as investigate how changes to the distraction might have implications for performance. This could contribute to a deeper understanding of the effect of distractions with changes attributes over time.

Previous studies have not found evidence for long term habituation to auditory noise (Beaman, 2005; Hellbrück et al., 1996), but have shown evidence for short term habituation to auditory noise (see Banbury & Berry, 1997; Khalinghinejad et al., 2019; Rocchi & Ramachandran, 2020). Furthermore, one such study also found evidence to support that dishabituation could happen with just five minutes of silence (Banbury & Berry, 1997). This opens the question to whether some form of dishabituation, especially to auditory distraction, could happen between training sessions or between the trials in the experiment. In the experiment, several minutes could pass during which participants would not be exposed to either the auditory distraction or the visual distraction (e.g., when they were exposed to auditory distraction only or video distractions only). Furthermore, between trials there were breaks that included visual stimuli including a movie clip and auditory stimuli including music, which may have impacted the participants ability to adapt to the distraction, especially for the auditory distraction (see Banbury and Berry, 1997).

Previous research suggests adaptation to visual distractions may be more resistant to dishabituation than auditory distractions (see Banbury & Berry, 1997; Beaman, 2005; Hellbrück et al., 1996; Turatto & Pascucci, 2016; Vaina et al., 1995), however, the possibility of dishabituation for visual distraction cannot be immediately disregarded. This should be evident in a difference between the calculation performances in the distraction modalities over the three consecutive days. Future research could investigate the difference between habituation to auditory and visual stimuli, and maybe include a habituation period in the experiment like one of the previous studies did (see Banbury & Berry, 1997). The current study included an audiovisual experimental condition, which not many studies has done before. Future research might want to include such a modality combination, since this can shed further light on the differences between auditory and visual distraction stimuli in relation to habituation and to dishabituation. Although it lies outside the scope of the current hypotheses, investigation of the short-term habituation to distractions could be a possibility for further analyses with the current dataset.

Another view on the unexpected results, regarding long-term adaptation to distractions in the current study, is related to the time spent with the distraction. In one of the studies on habituation to visual distraction, the participants had to complete over 200 training sessions before they were fully habituated to the stimuli, which means 200 repetitions of judging movement of a dotted pattern with visual distraction (Vaina et al., 1995). In the current study, while number of calculations tasks each participant completed could differ, all were exposed to the same amount of distraction during the 20 minutes long experiment. Therefore, the particiapants were approximately exposed to 180 distractions in one trial, which makes little more than 1000 distractions each day. In the audiovisual trial however, there was auditory and visual distractions simultaneously. If one counts them as double, the participants were exposed to almost 1500 distractions each day. This number is higher than in the previous research. However, in the previous study, the task was integrated with the distraction (Vaina et al., 1995). In the current study the distraction functioned more as background disturbances. Background distractions might be more distinct than integrated distractions, which could make the distractions either more prominent or less prominent. However, more or less prominent does not necessarily mean more or less distracting. Therefore, it might be difficult to compare the previous study with the current study on the number of exposures to distractions. Furthermore, the participants might need more time with auditory distractions, maybe up to 20 minutes for habituation to occur (Banbury & Burry, 1997; Khalinghinejad et al., 2019). Evidence from visual habituation shows that spontaneous recovery from the habituation is less likely to happen after the participants have been fully habituated (Turatto & Pascucci, 2016). Full habituation on day one might therefore be necessary for the habituation to last over several days.

The participants in the current study were young adults. Previous research show that habituation to visual distraction might happen easier for this group of individuals than older adults (Rozek et al., 2012). Some evidence for habituation to both auditory, visual and audiovisual distraction was found in the current study, since there was a significant improvement in reaction time from day 1 to day 2, for all the modalities, and a significant improvement in the visual condition only from day 2 to day 3. However, more research is needed to further investigate the adaptation to audiovisual distractions for both younger adults and older adults.

Whether habituation to distraction can transfer to different tasks or real-world situations is questionable. One previous study showed that distractions can have a negative effect on very specific tasks (Dent, 2010). Furthermore, habituation to visual noise in discrimination of movement leftward and rightward did not transfer to discrimination of movement upward and downward (Vaina et al., 1995). This, however, might be related to the differences in the two tasks and not directly related to the visual distraction. Still, one should consider whether learned adaptation in the lab actually can be transferred to other experimental settings and real-world situations.

### Reaction time, efficiency and accuracy

The dependent variables in the current study were measured with the participants' reaction times on each specific mathematical task, with percent tasks completed for each trial (efficiency), and with percent tasks correct of the completed tasks (accuracy). The reaction times are tightly connected to the efficiency measure; the lower the reaction times, the higher the mean efficiency score. Including analyses on the individual reaction times made it possible to investigate the effect of the distraction in more detail. However, since the participants completed a different number of tasks during the given time, and since there was a different number of tasks available for the easy and difficult tasks, the percent tasks completed for each trial was needed in order to compensate for this. Results for reaction time and the results percent tasks completed were expected to show similar tendencies because of the correlation between the two measures.

This being said, the differences in the results for the efficiency measure and the accuracy measure are worth noticing. The control condition had the lowest accuracy scores on all of the three days. This stands in contrast to the reaction time and efficiency for the control condition which showed a different pattern on day 2 and 3. Furthermore, accuracy had no significant main effects for day or for difficulty. No interaction effects were found for the accuracy measure either. There might be several reasons for this. Firstly, the distraction might have a different impact on the efficiency and the accuracy of the mathematical calculations. The distraction might have a bigger effect on efficiency than accuracy. However, because the distraction did not have a negative effect on the calculations, it is difficult to discuss potential differences further. Previous studies that included both reaction time measure and accuracy measure found negative distraction effects on both measures (see Banbury & Berry, 1997; Dent, 2010; Forster & Lavie, 2008; Tellinghuisen & Nowak, 2003). Secondly, many of the participants had full scores (100% correct) on the accuracy measure in the different experimental trials, which might explain the results.

The experiment had no repeating tasks within one version of the experiment, and no repeating tasks across the three days. This could explain why the control condition had the lowest accuracy measure on all of three days. The tasks were always new, but the distraction and the time the participant had to complete the tasks were the same. The participants might therefore do better with efficiency than with accuracy. The reason for why there was no significant main effect difficulty for the accuracy measure might be related to the cognitive processes associated with mathematical calculation. The difficult tasks might demand more working memory capacity; however, this might have a larger impact on the time it takes to solve the math tasks than whether the answer is correct or not. The efficiency measures and the accuracy measure might be further interconnected, where higher efficiency might lead to lower accuracy, and where higher accuracy might lead to lower efficiency.

The results of the current study might have implications for how we understand auditory and visual distraction in learning situations, in school or at the workplace, for example. The combinations of task type and distraction type might play a significant role for whether or not the distractions actually are distracting, and furthermore, how distracting they are. However, the experimental design might also have a say in this matter, and there might be significant differences between a learning situation in the lab and in real life.

## Concluding remarks

The aim of this study was to investigate the effect of auditory, visual, and audiovisual distraction on both easy and difficult mathematical calculation tasks, over the span of three consecutive days. Previous research has found negative effects of both auditory and visual distraction on various cognitive tasks (Beaman, 2005; Dent, 2010; Gao et al., 2012; Heim & Keil, 2019; Klatte et al., 2013). Furthermore, research supporting the perceptual load model has found that visual distraction has less of a negative impact on difficult visual tasks, as compared to easy visual tasks (Forster & Lavie, 2008; Lavie, 1995; Lavie, 2005; Tellinghuisen & Nowak, 2003). Previous research has also found evidence of long-term habituation to visual distraction over the span of three consecutive days (Turatto & Pascucci, 2016; Vaina et al., 1995). Hypotheses based on this previous research were created.

Norwegian university students between the ages of 18 to 28 participated in a distraction experiment three days in a row, where they gave their answer to easy and difficult math tasks presented on a computer. The participants solved the tasks in their heads and were simultaneously exposed to auditory, visual, and audiovisual distractions. The participants were measured on reaction time, percent task completed (efficiency) and percent tasks correct (accuracy). Results revealed no significant negative distraction effect on math performance, rather the distractions seemed to have a positive effect on the calculations. In terms of reaction time, some evidence was found to support the perceptual load model. The math performances got significantly better over the three days. However, compared to the control condition, only tendencies of habituation to the distractions were found. The visual condition was the only condition to have a significant improvement in reaction time from day 2 to day 3, and all the distraction conditions showed larger improvement in reaction time and efficiency than the control condition from day 2 to day 3.

Future research should investigate the long-term effect of distraction on easy and difficult mathematical calculation further, and consider the nature of the cognitive task and the nature of the distractions. The results of the current study show that audiovisual distractions might not be distracting in all circumstances, but might actually be helpful and improve performance on mathematical calculations. Furthermore, long-term adaptation to audiovisual distraction might happen with training over a longer time period. This might have implications for how we view distractions in different learning situations.

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## Appendix A

## Information letter and consent form

# Vil du delta i forskningsprosjektet

## «Påvirkning av auditiv og visuell informasjon på matematisk oppgaveløsning»?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke påvirkning av auditiv og visuell informasjon på matematisk oppgaveløsning. Matematikkoppgavene krever kun grunnleggende kunnskap om addisjon og subtraksjon. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

### Formål

Formålet med prosjektet er å undersøke påvirkning av auditiv og visuell informasjon på nøyaktighet og effektivitet ved matematisk oppgaveløsning. Prosjektet vil også undersøke om individer tilpasser seg til ulike audiovisuelle omstendigheter over tid. Ved å måle nøyaktighet og effektivitet ved tre ulike tidspunkter i løpet av tre dager kan prosjektet observere en eventuell forskjell i oppgaveløsningen.

Problemstillingene i prosjektet er:

- Hvilken påvirkning vil auditiv, visuell og audiovisuell informasjon ha på effektivitet og nøyaktighet ved matematisk oppgaveløsning?
- Tilpasser individer seg til auditiv, visuell og audiovisuell informasjon under matematisk oppgaveløsning over tid?

Prosjektet gjennomføres som en del av en masteroppgave tilknyttet masterstudiet i psykologi ved NTNU, retning læring – hjerne, atferd og omgivelser. Prosjektet kan publiseres internasjonalt, og benyttes ved internasjonale konferanser, men deltakere i prosjektet vil ikke kunne identifiseres.

### Hvem er ansvarlig for forskningsprosjektet?

Norges teknisk-naturvitenskapelige universitet (NTNU) er ansvarlig for prosjektet.

### Hvorfor får du spørsmål om å delta?

Du får spørsmål om å delta da prosjektets målgruppe er studenter ved NTNU med alder fra 18 til 28 år, som har normal hørsel og normalt/korrigert til normalt syn.

### Hva innebærer det for deg å delta?

Dersom du velger å delta i prosjektet vil det innebære å møte opp i 30-40 minutter tre dager på rad. Hver dag løser du matteoppgaver under ulike audiovisuelle omstendigheter. Matteoppgavene krever kun grunnleggende kunnskap om addering og subtrahering. Oppgaveløsningen foregår på en datamaskin hvor du taster inn svaret. Svaret og hvor mange oppgaver som gjennomføres lagres elektronisk. Før oppgaveløsningen besvarer du en kort spørreundersøkelse. Spørreundersøkelsen inkluderer spørsmål om kjønn, alder, erfaring med kalkulering og ja/nei-spørsmål om helsehistorikk og medikamentbruk som eventuelt kan påvirke oppmerksomhet, kalkulering, syn eller hørsel. En forkortet versjon av spørreundersøkelsen besvares ved andre og tredje oppmøte. Etter fullført gjennomføring vil alle deltakere motta en liten premie, og alle er samtidig med i trekningen av seks midtbyen gavekort på 250 kroner.

### Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

**Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger**
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Ved NTNU vil kun veileder, masterstudent og interne medarbeidere ha tilgang til dine personopplysninger.
- Samtykke, kontaktinformasjon og svar på spørreundersøkelser kobles til en deltakerkode og holdes adskilt fra svarene i eksperimentet.
- Du vil ikke kunne gjenkjennes i publikasjon av masterprosjektet, andre publikasjoner eller presentasjoner basert på data samlet til prosjektet.
- Ingen personidentifiserende informasjon vil oppbevares etter prosjektslutt.

**Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?**
Personopplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er innen 1. juni 2023. Koden tilknyttet personopplysningene slettes og personidentifiserende opplysninger makuleres.

**Hva gir oss rett til å behandle personopplysninger om deg?**
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

**Dine rettigheter**
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- NTNU ved veileder Dawn Marie Behne på epost (dawn.behne@ntnu.no) eller på telefon: 92 05 30 96.
- Masterstudent Ine Stensholm Elveland kan kontaktes på epost (inee@stud.ntnu.no) eller på telefon: 98 62 96 19.
- Vårt personvernombud: Thomas Helgesen kontaktes på epost (thomas.helgesen@ntnu.no), eller telefon: 93 07 90 38.

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Dawn Marie Behne
(Forsker/veileder)

Ine Stensholm Elveland

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# Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Påvirkningen av auditiv og visuell informasjon på matematisk oppgaveløsning», og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i eksperimentet

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

\-----------------------------------------------------------------------------------------------------------
(Signert av prosjektdeltaker, dato)
¨

## Appendix B

## Questionnaire

# Spørreskjema for forskningsprosjektet

«Påvirkning av auditiv og visuell informasjon på matematisk oppgaveløsning»

Tusen takk for at du ønsker å delta! Under følger noen bakgrunnsspørsmål. Vennligst kryss av/fyll inn det svaret som gjelder for deg. All informasjon vil behandles konfidensielt. Svarene nedenfor vil kobles til svarene dine i eksperimentet ved hjelp av en kode, men ikke til navn eller annen identifiserende informasjon. Skjemaene vil bli makulert innen 1. juni 2023.

Dato: ________ Forsker: ________ Deltakerkode: ________

---

1. Kjønn: ______ Ønsker ikke å oppgi ☐

2. Alder: ______

3. Vennligst bekreft at du oppfyller utvalgskriteriene om normal hørsel og normalt/korrigert til normalt syn (korreksjon er f. eks. briller eller linser).

Ja ☐ Eventuell kommentar: ___________________________

4. Hvor ofte i jobb-/studiesammenheng gjør du matematiske kalkulasjoner uten kalkulator?

Daglig ☐ Ukentlig ☐ Månedlig ☐ Sjelden ☐ Aldri ☐

5. Når deltok du sist i jobb/undervisning med matematiske kalkulasjoner? Årstall: ________

6. Har du helsehistorikk eller noe ellers som kan påvirke oppmerksomhet, kalkulering, syn eller hørsel (hjernerystelse siste 6 mnd., ADHD, dyskalkuli, eller lignende)?

Ja ☐ Nei ☐

7. Tar du medikamenter i dag som kan påvirke oppmerksomhet, kalkulering, syn eller hørsel?

Ja ☐ Nei ☐

8. Hvordan er din generelle form i dag?

Veldig bra ☐ Ganske bra ☐ Grei nok ☐ Kunne vært bedre ☐ Dårlig ☐

9. Føler du deg opplagt i dag?

I stor grad ☐ I noen grad ☐ Hverken/eller ☐ I liten grad ☐ I svært liten grad ☐

10. På hvilke av følgende oppgaver ville du benyttet kalkulator?

53 + 24 ☐

54 – 78 ☐

176 + 388 ☐

36 – 14 ☐

38 + 49 ☐

86 – 58 ☐

266 – 147 ☐

235 + 124 ☐

35 + 22 ☐

Ingen av oppgavene ☐

Tusen takk for dine svar!

## Appendix C

## Handedness questionnaire

# Hendthet

Dato ________

Tester ____________

Deltager kode ________

Vennligst oppgi med hvilken hånd du utfører følgende gjøremål. Prøv ut og se for deg hvordan du gjennomfører hver oppgave.

Sett et kryss i den tilhørende kolonnen.

| | | **Bare venstre** | **Foretrekker venstre** | **Begge** | **Foretrekker høyre** | **Bare høyre** |
|---|---|---|---|---|---|---|
| 1. | Kaste en dartpil | | | | | |
| 2. | Bruke strykejern | | | | | |
| 3. | Bruke en datamus | | | | | |
| 4. | Skru av en flaskekork | | | | | |
| 5. | Ta av tape fra en taperull | | | | | |
| 6. | Male et bilde | | | | | |
| 7. | Pusse tennene | | | | | |
| 8. | Klippe med saks | | | | | |
| 9. | Tegne | | | | | |
| 10. | Tenne fyrstikker | | | | | |
| 11. | Pusse sko med | | | | | |
| 12. | Kaste en ball med | | | | | |

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