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Spot the dangerous situations

EEG measurements of hazard perception in adolescent cyclists

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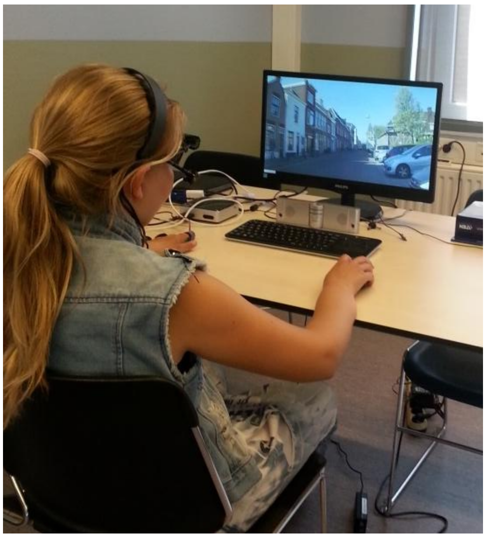

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Spot the dangerous situations: EEG measurements of hazard perception in adolescent cyclists

by

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The present thesis includes two studies both investigating attention in cycling. The first study was conducted since the second study was meant to measure EEG activity in adolescents while cycling in real traffic. However due to ethical issues the second study was changed into a computer hazard perception task. Nonetheless the first study has added value since it tested the influence of physical activity on the attention score output of the NeuroSky Mindwave EEG device. It was found that physical activity seemed to influence the signal however, the device was able to distinguish between no task and arithmetic tasks with its attention output. Nonetheless, the results of study 1 suggest that the attention score of the Mindwave device is not usable for research since the found attention score was higher when doing nothing than when doing arithmetic tasks in the sitting condition. The second study investigated whether adolescents perceive danger differently than adults, whether their attention level differs for hazards and whether their reaction times towards possible hazards differ. The results of this study suggest that there are no differences between adults and adolescents. It is discussed that adolescents possibly have the same hazard perception skills and that the cause for their risky behavior lies somewhere else.

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1. Introduction

Peter is cycling to his secondary school. He has an important test today and he does not want to be late. He has 10 minutes left before the test starts and the school is not in sight yet, therefore he is cycling as fast as he can. Suddenly he hears a car honking. Peter looks towards the direction of the honking and sees two headlights coming right at him. He closes his eyes, bracing for impact. Tires squeak and then nothing. He opens his eyes and sees that he just missed the car. Relieved as he is, he ignores the yelling from the car driver. The car driver must have been shocked too. Peter takes a deep breath and continues his way to school, albeit at a slower pace.

Luckily, the secondary school student in the fictional story above did not get involved in a traffic accident. However, in the real world, traffic crashes are one of the main causes of death among adolescents (Sleet, Ballesteros, & Borse, 2010; Twisk, Bos, Shope, & Kok, 2013). This phenomenon is probably caused by two main things. First, adolescents take more risks than any other age group (Chinn, Elliott, Sentinella, & Williams, 2004; Elliott & Baughan, 2003; Granié, 2009; Woldringh & Katteler, 2002). For example in more detail, Elliot and Baughan (2003) identified different unsafe and risky road behaviours, such as running across the road without looking, and showed that adolescents aged 13 to 16 engaged more in these unsafe road behaviours than 11 to 12 year olds. Second, adolescents are exposed to longer and more complicated school routes than younger children since they now go to a secondary school instead of an elementary school (Chinn, et al., 2004). Besides this changed route, adolescents in the Netherlands also travel mostly by bike due to the same shift to a secondary school (Twisk, et al., 2013). Since bicycles are relatively often involved in traffic accidents, this also results in many bicycle accidents among adolescents, some of them even fatal. In the Netherlands in 2014, 13 out of 19 fatal traffic accidents among people younger than 15 years happened while they rode a bicycle (CBS, 2015). These outcomes indicate that there is a critical problem for cycling adolescents in traffic that needs to be addressed. Therefore the present thesis analyses risk taking in adolescents in the age of 12 to 14 years, the age adolescents recently shifted to a secondary school in the Netherlands.

It should be noted that the aim of this thesis is not to discourage adolescents from cycling, though it is the aim to make cycling safer for them by investigating the elevated amount of risk taking. Different study outcomes and different theories already exist for explaining risk taking in adolescents. One explanation for the higher level of risk taking is the developing brain. Although the socio-emotional system is (almost) matured in adolescents, the cognitive control system will keep on developing until the mid-twenties (Boyer, 2006; Brijs, Ruiter, & Brijs, 2009; Steinberg, 2007). The socio-emotional system is developed during early adolescence, making adolescents very sensitive to social and emotional stimuli, and plays an important role in reward processing. The cognitive system is developed later in late adolescence, this system is involved in cognitive tasks such as planning, self-regulation and thinking ahead (Brijs, et al., 2009; Steinberg, 2007). Due to this underdeveloped cognitive system and sensitive socio-emotional system, adolescents have less control to stop taking risks.

The growing social environment is another important factor in risk taking behaviour. Even though it is true that humans from all age groups show more risk taking in groups in comparison to risk taking when being alone, (Bougheas, Nieboer, & Sefton, 2013; Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; Morrongiello, McArthur, Kane, & Fleury, 2013; Morrongiello & Sedore, 2005), 13-14 year olds show even more risk taking when in a group than older or younger people do in a group (Chinn, et al., 2004; Gardner & Steinberg, 2005). A possible explanation might be that the larger social environment in combination with a sensitive socio-emotional system enlarges each other's effects on the adolescent's behaviour.

Another possible explanation for risk taking in adolescents is the deceased danger perception in adolescents. Granié (2009) shows that danger perception decreases significantly between seventh grade (12-13 year olds) and tenth grade (15-16 year olds). This drop in danger perception indicates that the younger children perceive the level of danger to be higher for the tested situations than older children. Therefore adolescents might, at least part of the time, take risks due to not knowing the dangers behind their behaviour. For the present study, the term hazard perception is used instead of danger perception. The definition used in the paper of Vlakveld (2014) is used in this thesis as well. Vlakveld (2014) combines the definition of hazard perception from Horswill and McKenna (2004) and the definition of situation awareness of Endsley (1995) to define hazard perception as having three distinct levels. Level 1 involves the ability to detect possible hazards, level 2 involves the ability to recognize possible hazards, and level 3 involves the ability to predict how the possible hazard could develop to result in a crash.

These studies show that adolescents indeed take risks. However, it still remains unknown what best can be done to prevent them from taking risks. To investigate this risk taking the present thesis focuses on hazard perception. Something that has been investigated in combination with hazard perception is cognitive load (Sagberg & Bjørnskau, 2006) which is defined as the attentional resources needed to meet a certain performance criteria (Young & Stanton, 2005). A more recent used measure for investigating hazard perception is electroencephalography (EEG). For example, Savage, Potter and Tatler (2013) used EEG in a study which tested hazard perception in relation to preoccupation of a recent phone call. They let participants have a conversation and manipulated cognitive load, by letting the participants solve a riddle after the phone call in the high cognitive load condition and gave no riddle in the no cognitive load condition. Their results show that that high cognitive load decreased the reaction times to hazards. Another finding is that in the high cognitive load condition, the EEG measurements of theta activity were increased, indicating greater task difficulty (Gevins, Smith, McEvoy, & Yu, 1997; Ryu & Myung, 2005) and possibly explaining the longer reaction times.

However, Savage, Potter and Tatler (2013) used traditional research EEG equipment, which is not very comfortable, nor is it highly mobile. Therefore, traditional EEG devices are not very suitable for use in more realistic testing settings. A possible solution studied in the present thesis might be a mobile EEG device such as the NeuroSky Mindwave EEG device. This device is wireless and therefore very mobile, and is also more comfortable. However, this device only has one electrode and a ground electrode, whereas traditional EEG devices have multiple electrodes distributed over the head.

Johnstone (2012) shows that for the NeuroSky MindSet® (an older device using the same technology) the frequency spectra have a correlation with traditional research EEG equipment frequency spectra of r=0.89. Besides that, the attention score is found to be positively correlated with self-reported attention (r=-.391) (Rebolledo-Mendez et al., 2009). However, before it is possible to use the Mindwave in a reliable manner in traffic safety research, different aspects and possible influencers on the signal need to be tested.

Aspects and possible influencers on the signal could come from muscle movements, activity in other parts of the cortex than beneath the electrode, the heartbeat, electromagnetic interference from other electronics, the sensor moving over the skin as well as sweating. In context of cycling adolescents, it is interesting to know if this measure says something about the attention someone has while cycling in possible hazardous situations and if adolescents are worse at hazard perception than older and more experienced cyclists. The current thesis therefore, addresses these questions. To investigate this, two studies were conducted. First, a study was conducted to investigate the possible influence of physical activity to the output of the Mindwave device. This study investigates the usability of the Mindwave device while riding a bike. This study was executed since at first the aim of the second study was to measure EEG activity while letting adolescents cycle through traffic. However, due to ethical issues the second study was changed into a hazard perception task on a computer involving movies recorded in traffic. Nonetheless, the first study was already conducted and the results from this study are still relevant for future research. The second study investigates hazard perception and attention in hazardous situations in adolescents compared to adults. Therefore, the main research question of the current thesis asks whether a difference exists between adolescents and adults when cycling through possible hazardous situations of traffic.

The first study includes one sub-question concerning physical activity and the possibility of it interfering with the output signal of the NeuroSky Mindwave EEG device. It is expected that physical activity does not disturb the signal too much, since the motor areas lie further back in the parietal areas of the brain, whereas the Mindwave device measures brain activity on approximately the location of the left dorsolateral prefrontal cortex (DLPFC) which is situated in the frontal lobes. It is also expected that cognitive load increases the attention score, since the definition of Young and Stanton (2005) explains that a higher cognitive load should increase attention to reach the same performance criteria as a lower cognitive load. Therefore, more cognitive demanding tasks are expected to increase the attention score. This increase in attention would then make it possible to discriminate between different states of cognitive load with the Mindwave device. Since it is expected that physical activity does not interfere too much with the output signal of the Mindwave device, the device should still be able to discriminate between different states of cognitive load when cycling.

The second study includes three sub-questions. First it is asked if adolescents and adults differ in their hazard perception skills. It is expected that adolescents are worse at perceiving danger than adults are, due to the danger perception drop demonstrated by Granié (2009). Secondly, it is asked if adolescents have less attention for possible hazardous situations than adults have. Since it is expected that adolescents are worse at hazard perception skills, they are expected to perceive less hazards. Due to this assumption, it is also expected that adolescents have less attention for possible hazardous situations since they do not perceive the situations to be so. Lastly, it is asked if adolescents and adults differ in the amount of time they take before reacting to possible hazards. It is expected that adolescents take longer to react to possible dangers than adults, because the cognitive control system of adolescents is not fully developed yet (Boyer, 2006; Steinberg, 2007). Due to the immature cognitive control system it is possible that the secondary school students do not cognitively anticipate that something might develop into a dangerous situation. However, the moment the situation gets more dangerous it might elicit a more emotional reaction in the adolescents due to the (almost) matured social-emotional system (Boyer, 2006; Steinberg, 2007). Therefore adolescents are expected to wait longer before reacting to a possible danger.

2. Methods study 1

2.1 Design

The research method in the first study is experimental and includes a within-subjects design. The two conditions differ in physical activity, in the sitting condition the participant is in rest while sitting in a chair, the cycling condition involves cycling on an exercise bike. The independent variable is the cognitive load state (rest versus arithmetic task). The dependent variable is the output of the Mindwave device (the attention score). All participants executed the same tasks in the same order.

2.2 Participants

The first study consisted of a sample of in total ten employees of the SWOV Institute of Road Safety Research, four males and six females. The sample also included interns doing their internship at SWOV. All participants were in the age of 21 to 51, with a Mean of 28 years. The participants voluntarily participated in the study and were recruited via an advertisement on the intranet page of the company as well as via verbal advertising.

2.3 Materials

2.3.1 EEG measurements. The EEG device which was used during the experiment is the NeuroSky Mindwave EEG device; see Figure 1 on the next page for a picture of the device. The NeuroSky Mindwave EEG device is very mobile and is worn over the head like headphones. It includes a single electrode. However, traditional EEG devices have multiple electrodes distributed over the head. The placement of traditional EEG electrodes happens usually according to one of various international systems, such as the 10-20 system. This system has certain regulations about the location of the electrodes on someone's head in order to compare the EEG output between participants. The single electrode of the NeuroSky Mindwave EEG device is placed on the forehead, approximately on the Fp1 position according to the 10-20 system which is about the location of the left dorsolateral prefrontal cortex (DLPC). In essence the NeuroSky Mindwave EEG device trades the ability to take a full brain spectrum for mobility. The device also includes a small ear clip with an electrode that functions as the reference (ground) electrode.

The NeuroSky Mindwave EEG device outputs an attention score, a value ranging from 1 to 100. According to NeuroSky, an attention value between 40 and 60 stands for a neutral amount of attention. A value between 60 and 80 refers to slightly heightened attention and a value between 80 and 100 refers to strongly heightened attention. In the same way, a value between 20 and 40 refers to slightly decreased attention and a value between 1 and 20 refers to strongly decreased attention. However, it is important to note that interpersonal differences in attention values can be high. Lastly, a value of zero indicates that the NeuroSky Mindwave EEG device is unable to calculate a reliable score which is generally due to excessive noise (NeuroSky, 2014). The NeuroSky Mindwave EEG device also automatically filters the signal for artefacts and noise.

Figure 1. The NeuroSky Mindwave EEG device.

2.3.2 Physical activity. To investigate whether physical activity interferes with the attention output of the Mindwave device, three tasks were carried out. All three tasks were carried out in two conditions. The two conditions were; the sitting condition, which involved sitting still in a chair while executing the tasks, and the physical activity condition, which included cycling in a steady rhythm on an exercise bike while simultaneously executing the tasks. The three tasks that were carried out in both conditions are the ‘no task’, which involved trying to think about nothing, and the other two tasks both were arithmetic tasks; counting backwards and basic mathematical operations. The counting backwards task involved counting backwards with steps of seven for five minutes. The starting point on where to start counting backwards differed for the sitting condition and the physical activity condition to prevent memorizing the numbers and inducing proper cognitive attention. For the sitting condition the counting started from 700 and for the physical activity condition the counting started from 625. The basic mathematical operations task included solving simple mathematical calculations such as multiplying, dividing, adding, and subtracting for five minutes.

2.4 Procedure

The employees were recruited via an advertisement on the intranet of the SWOV and via verbal advertising. First, the participants received a short verbal explanation about the study and after consenting to the experiment, the equipment was put on. Second, the participants were asked to sit still on a chair in a comfortable position and received instructions to think about “nothing” for five minutes. Next, while still sitting in the chair, the participants were asked to execute the two different arithmetic tasks.

Thereafter, the participants executed the same three tasks while simultaneously cycling on an exercise bike. During all tasks, speed nor accuracy were the main goals as long as the participants were cognitively busy calculating. Therefore, the participants were allowed to start over if they lost their count while counting backwards and as well were able to skip one mathematical operation if it was too hard for them in order to keep them cognitively busy. After having finished all tasks in both conditions, the participants completed the study and had to put off the equipment. Lastly, the participants were thanked for their participation.

2.5 Data analysis

The Mindwave device automatically outputs an attention score, which was used for the data analysis. The Mean attention score for each participant during one task was compared with the Mean attention score for each participant during another task. A Wilcoxon signed-rank test was used to test for differences between the attention score during the three different tasks; when thinking about nothing, when counting backwards, and when performing basic mathematical operations. This was done for both the sitting condition as well for the physical activity condition. A Wilcoxon signed-rank test was used since the sample was not normally distributed. For effect sizes the pooled Cohen’s *d* was used.

3. Results study 1

For all statistical tests an alpha level of .05 was used. For the first study a Wilcoxon signed-rank test was conducted since the sample was not normally distributed.

Significant within-subjects effects of the attention score between no task and both arithmetic tasks were found in the sitting condition, Z= 9.1503, *p*<.001, *d*=1.2034, for the difference in attention score between no task and basic mathematical operations, and Z=9.2264, *p*<.001, *d*=1.1902, for the difference in attention score between no task and counting backwards. However, no significant within-subjects effect of the attention score was found between the two arithmetic tasks, Z=-.3737, *p*=.71 for the difference in attention score between basic mathematical operations and counting backwards. See table 1 for the Means and Standard Deviations of the attention score for each task in the sitting condition.

In the physical activity condition, again within-subjects effects were found for the difference in attention score between no task and both arithmetic tasks. Significant within-subjects effects were found for the difference in attention score between no task and basic mathematical operations, Z=-2.8026, *p*=.0051, *d*=.2416 and between no task and counting backwards, Z=2.2126 *p*=.0269, *d*=.1696. Again, no effect was found for the difference in attention score between basic mathematical operations and counting backwards when cycling, Z=1.0004, *p*=.3171. See table 2 for the Means and Standard Deviations of the attention score for each task in the physical activity condition.

Table 1

Means and Standard Deviations of the attention score per task in the sitting condition.

Task	Mean	Standard Deviation
No Task	54.3990	12.3266
Basic mathematical operations	40.2816	11.1043
Counting backwards	40.5776	10.8529

Table 2

Means and Standard Deviations of the attention score per task in the physical activity condition.

Task	Mean	Standard Deviation
No Task	43.7266	14.3409
Basic mathematical operations	47.0025	12.7276
Counting backwards	46.0025	12.4241

4. Discussion study 1

The Wilcoxon signed-rank tests which were conducted show that the Mindwave device is able to discriminate between different tasks in both the sitting condition as in the physical activity condition. However, in the sitting condition the Mean attention score was larger during the no task than during one of the arithmetic tasks, nonetheless a large effect size was found. This is not in line with the definition of cognitive load, both arithmetic tasks increase the cognitive load compared to thinking about nothing which should increase the attentional resources to meet the performance criteria (Sagberg & Bjørnskau, 2006). Besides that, previous research such as the study of Savage, Potter and Tatler (2013), showed that high cognitive load compared to no cognitive load changes brain activity measured with an EEG. Therefore, the findings of the current study are not completely in line with previous studies. The assumption of the study that the attention score of the Mindwave device is able to discriminate between situations that need little attention and situations that need a high amount of attention when sitting still is true. However, the direction of the attention score was in the opposite direction than expected. Besides that, no significant difference was found in attention score between the two arithmetic tasks; counting backwards and basic mathematical operations. This result indicates that both tasks required the same amount of attentional resources and probably both tasks had the same task difficulty, since brain activity would be expected to change when task difficulty increases (Gevins, et al., 1997; Ryu & Myung, 2005).

For the physical activity condition the same pattern of significance was found, although the significance level as well as the effect sizes of the difference between no task and the arithmetic tasks were less strong than in the sitting condition. Besides that, the Mean attention score now changed in the expected direction, compared to the no task, the attention score increased during both arithmetic tasks. This seems to imply that physical activity influences the output of the Mindwave device. However, it should be noted that the overall increase in amplitude of the brainwaves was increased in the physical activity condition in comparison to the sitting condition. This increase will largely be due to the increase in motor-cortex activity. Nonetheless it might partly be due to physiological changes such as an increase in heart rate resulting in more blood flow between the sensor and the brains, more sweating resulting in better conductance of the electrode and more movements with the head resulting in more noise signals. Nonetheless, these findings show that the Mindwave device is able to discriminate between cognitive loads even when someone is physically moving. Other studies using the Midwave device concluded that the device was a good tool for research

(Johnstone, 2012; Rebolledo-Mendez et al., 2009). However, in the present study the Mindwave device showed different directions of the Mean attention score in the sitting condition compared to the physical activity condition, which suggests that the Mindwave device does not seem to be a good tool to use in research in general.

5. Methods study 2

5.1 Design

The second study is quasi-experimental, in which the performance of adolescents and adults on a hazard perception task is compared. The study has a two by two between-subjects design and the independent variable is the age (adolescent or adult). The skill level at detecting hazardous situations in traffic situations is assumed to be higher among adults than among the adolescents, since the adults have more experience with traffic situations. The dependent variables are: reaction time, the score on the hazard perception task, and the attention score output of the NeuroSky Mindwave EEG device.

5.2 Participants

The sample used in the second study consisted of two groups. One group consisted of 17 employees of the SWOV, including 11 males and 6 females in the age of 22 to 59 with a Mean of 35 years. They were recruited via an advertisement on the intranet of the SWOV and via verbal advertising. The other group involved 27 secondary school students, consisting of 14 males and 13 females in the age of 12 to 14 with a Mean of 13 years. The secondary school students studied at the Northgo College in Noordwijk. This group was recruited via their teachers who distributed informational letters among their students in the age of 12 to 14 years. The secondary school students were enrolled in a "technasium" course, which is a hands-on, problem-driven education program. In context of this course it was possible for the secondary school students to participate in the study and get a voucher of ten euro's afterwards. All participants voluntarily participated in this study and all participants executed the same tasks.

5.3 Materials

For the employees of the SWOV, the instruments and equipment were installed in a meeting room inside the building of SWOV. For the secondary school students however, the instruments and equipment were installed in a meeting room at the secondary school. Due to the room being located inside the secondary school itself, the students could easily participate without missing a great amount of class. The experimental setup can be seen in Figure 2.

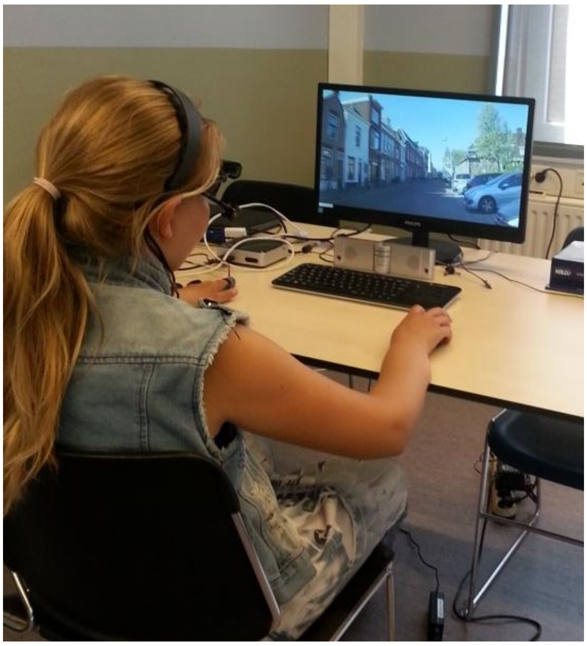

Figure 2. Experimental setup at the secondary school in Noordwijk.

5.3.1 EEG measurements. The EEG device which was used during the experiment is the NeuroSky Mindwave EEG device. See Figure 1 on page 9 for a picture of the device. As described in the method section of study 1, the NeuroSky Mindwave EEG device is very mobile and is worn over the head like headphones. It includes a single electrode. However, traditional EEG devices have multiple electrodes distributed over the head. The placement of traditional EEG electrodes happens usually according to one of various international systems, such as the 10-20 system. This system has certain regulations about the location of the electrodes on someone's head in order to compare the EEG output between participants. The single electrode of the NeuroSky Mindwave EEG device is placed on the forehead, approximately on the Fp1 position according to the 10-20 system which is about the location of the dorsolateral prefrontal cortex (DLPC). In essence the NeuroSky Mindwave EEG device trades the ability to take a full brain spectrum for mobility. The device also includes a small ear clip with an electrode that functions as the reference (ground) electrode.

The NeuroSky Mindwave EEG device outputs an attention score, a value ranging from 1 to 100. According to NeuroSky, an attention value between 40 and 60 stands for a neutral amount of attention. A value between 60 and 80 refers to slightly heightened attention and a value between 80 and 100 refers to strongly heightened attention. In the same way, a value between 20 and 40 refers to slightly decreased attention and a value between one and 20 refers to strongly decreased attention. However, it is important to note that interpersonal differences in attention values can be high. Lastly, a value of zero indicates that the NeuroSky

Mindwave EEG device is unable to calculate a reliable score which is generally due to excessive noise (NeuroSky, 2014). The NeuroSky Mindwave EEG device also automatically filters the signal for artefacts and noise.

5.3.2 Movies. All movies which were used in the hazard perception task were recorded with a GoPro Hero 3 Silver Edition Camera. The camera was attached to an adapted bicycle, which made it possible to record the area in front of the bike while cycling through traffic. Filming traffic with the adapted bike delivered hours of video footage. Together with two experts from the SWOV it was deliberated that a total of 16 movies would be included in the current study. One movie was used for the introduction of the hazard perception task, two movies were used to practice the hazard perception task, and the other 13 movies were included in the final hazard perception task itself. It was decided that each movie would have a length of between 25 seconds and one minute. The audio was removed from all movies and was not used in the present study. All movies were stabilized with Adobe Premiere Pro CC 2015, using the standard stabilizing option and standard settings, stabilizing each movie with a percentage of 50%.

5.3.3 Hazard perception task. In the second study, a video instruction explained the hazard perception task and included an example of a movie similar to the movies displayed in the task itself. This example movie included narrated audio of someone who is thinking out loud during the example movie. The test consisted out of 15 movies with durations between 35 seconds and one minute. The first two movies were practice movies, the remaining 13 were test movies, which later were being analysed and used for the results.

The method used in the hazard perception task is the same method used in task 2 in the study of Vlakveld (2014). This method was chosen since this method reflects real traffic; participants only see each movie once and have to react at the moment they detect a hazard. Each movie contained one or two possible hazards, which were picked after a deliberation together with two SWOV employees. However the participants did not know how many possible hazards were present in each movie. During all 15 movies the spacebar on the keyboard had to be pressed to indicate a possible hazard. However, it was explained that the situations in the movies would never actually become very dangerous. Pressing the spacebar could be done for a maximum of four times per movie. This was to prevent that participants pressed for every small detail and instead only pressed for things which they really thought might become dangerous. Whenever a participant pressed the spacebar a white marker appeared on the timeline at the bottom of the screen and a short beep sounded. However, the movie was not interrupted by it and kept playing at normal speed.

For the moments someone pressed the spacebar, an option menu appeared immediately at the end of each movie. In this option menu screenshots from the moment of pressing the spacebar were presented on the screen. Participants had to choose which of these hazards they found most dangerous by clicking on it with the mouse. The chosen screenshot appeared in full screen and the participant had to mark the hazard which they thought made the situation (possibly) dangerous by clicking on it. The software recorded the time of pressing the space bar as well as the coordinates of the mouse click to mark the hazard. For this task, two different versions were used. Both versions included the same movies, only the movies were presented in the opposite order.

5.3.4 Questionnaire. For the second study a short demographic questionnaire was conducted. This questionnaire provided general information such as gender, age and cycling habits. The duration of the questionnaire was approximately three minutes.

5.3.5 Electronic equipment. During the experiment two different computers were used. One Intel Nuc, model D54250WYK, running Ubuntu Linux and one HP ProBook laptop, Home OEM Edition, running Windows 7. The Intel Nuc computer was used to record the EEG measurements and the HP Laptop was used for the hazard perception task.

5.4 Procedure

The study was approved by the ethical committee of the SWOV. The parents of the secondary school students received an informed consent which had to be signed both by them and their child. During the study, the participants were invited into the room and were first asked to read a short text explaining the experiment. Second, the researchers helped the participants with putting on the equipment and subsequently conducted a baseline measurement. Thereafter the hazard perception task was started. Two different versions of this task were used both versions included the same movies, however in the opposite order. Which of the two versions of the hazard perception test a participant made was counterbalanced across the participants in order to mitigate learning effects. At the end of the hazard perception task, the participants took off the equipment and filled in the questionnaire. The participants were thanked for their participation and the secondary school students each received a ten euro voucher.

5.6 Data analysis

For the first sub-question if adolescents and adults differ in their hazard perception skills, a hazard perception score was calculated. This was done by scoring all participants individually for each movie. The participants received one point for a movie if they pressed the space bar for the right hazard. They received three points for a movie if they also chose the right hazard as being the most dangerous situation of the movie by clicking on the corresponding screenshot. Three movies (1, 2 and 9) included two hazards, for these movies it was possible to receive a maximum of four points by pressing the spacebar for both hazards and choosing one of the hazards as being the most dangerous situation of the movie. The score of all movies were combined for each participant and the adults and experts were compared by conducting an independent samples t-test.

For the second sub-question, the automatic attention score output of the Mindwave device was being used in the data analysis. For each press on the spacebar during a movie of the hazard perception task, a window of two seconds before the press and three seconds after the press was made; this is later referred to as the attention score when pressed. The Mean attention score of this window was being calculated and for all presses in one movie a total Mean was calculated and analysed in a repeated measures ANOVA compared to the Mean attention score over the whole movie. Later it is also compared with a repeated measures ANOVA for each separate movie. Also for each hazard in the movies a time window was created, the starting point of the window was the moment the possible hazard was first visible and the end of the window was the moment that a reaction to the hazard would have been to late if it would have become a real danger. These hazard windows were determined in deliberation with two SWOV employees. For the hazard windows a repeated measures ANOVA was used to analyse the attention score compared to the whole movie. Again, repeated measures ANOVAs were also used to compare the windows with each concurring movie separately. See appendix A for examples of different attention windows.

For the third and last sub-question about the reaction time of adolescents and adults to possible hazards, two different methods were analysed. First, the time they pressed the space bar for one of the right hazards was calculated into percents of the hazard window. If a participant did not press during that particular hazard, his or her score would be 100 as this is the worse score one could obtain. How faster someone is, the better he or she is at detecting the hazard, therefore not detecting the hazard at all or at least not in the preset window scores the full 100 percent. All percentages of each movie were added and this score was compared for both groups. Second, again percents were calculated, however now participants got a bonus when they selected the right screenshot as being the most dangerous situation. The bonus included dividing the percentage of that movie in half. Again, all percentages of each movie were added and this score was compared for both groups. All analyses included an independent samples t-test.

Lastly, it should be noted that there were some technical problems and as a result not all participants who participated could be included or only included in the analyses for some of the movies. Besides, for the second sub-question when someone did not press during a movie he or she cannot be included in the Mean attention score when pressed. The sample sizes are therefore mentioned for each test.

6. Results study 2

For all statistical tests an alpha level of .05 was used. The independent samples t-test for the first sub-question did not show a significant effect on the hazard perception score between adolescents (*N*=27) and adults (*N*=17), *t*(42)=.142, *p*=.888. For the adolescents the Mean score was 22.111 with a Standard Deviation of 5.605. The Mean score of the adults was 21.824 with a Standard Deviation of 7.820.

For the second sub-question a repeated measures ANOVA was conducted for each hazard window as well for the presses on the spacebar. Comparing the total Mean attention score of all movies with the total Mean of all presses (adults (*N*=12), adolescents (*N*=25)), a main effect of attention was found, *F*(1,35)=24.354, *p*<.001, partial eta squared=.410. The Mean attention score during the whole movie was 49.412 with a Standard Deviation of 7.069. The Mean attention score when pressing the spacebar was 51.935 with a Standard Deviation of 7.158. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,35)=.058, *p*=.811, nor a between-subjects effect of expertise was found, *F*(1,35)=.115, *p*=.737. Comparing the total Mean attention score of all movies with the total Mean of all windows (adults (*N*=12), adolescents (*N*=25)), a main effect of attention was found, *F*(1,35)=16.073, *p*<.001, partial eta squared=.315. The Mean attention score during the whole movie was 49,412 with a Standard Deviation of 7.069. The Mean attention score during the hazard window was 52,065 with a Standard Deviation of 7,671. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,35)=1.196, *p*=.282, nor a between-subjects effect of expertise was found, *F*(1,35)<.001, *p*=.983.

Since it is too much data to show here, only the significant effects are shown. For a written section of all test results whether or not significant see appendix B. An interaction effect of attention and age (adult or adolescent) was found in movie 1 for comparing the Mean attention scores for adolescents and adults during the whole movie and during the second hazard window, *F*(1,32)= 5.849, *p*=.021, partial eta squared=.155. For the descriptive statistics belonging to this interaction effect see table 3. For the significant main effects of attention comparing the attention scores during the whole movie and during the hazard window, see table 4. For the significant main effects of attention comparing the attention scores during the whole movie and when pressing the space bar, see table 5.

For the third sub-question about reaction time, the percentages of the time the participant pressed the space bar in the hazard window do not show a significant effect between adolescents and adults, *t*(42)=.512, *p*=.612. For the adolescents the Mean score was

9.420 with a Standard Deviation of 2.000. The Mean score of the adults was 9.811 with a Standard Deviation of 3.092. When the bonus was included still no effect was found between adolescents and adults, *t*(42)=.074, *p*=.942. For the adolescents the Mean score was 8.732 with a Standard Deviation of 2.179. The Mean score of the adults was 8.791 with a Standard Deviation of 3.185.

Table 3

Descriptive statistics of the interaction effect in movie 1

	Age	Mean	SD	*N*
Whole movie	adult	49,244	7,807	11
	adolescent	50,143	8,054	23
	Total	49,852	7,867	34
Hazard window 2	adult	42,515	15,407	11
	adolescent	53,768	12,407	23
	Total	50,1275	14,251	34

Table 4

Results for the main effects of attention comparing the attention score during the whole movie and during the hazard window per movie.

Movie	*N*	df Error	*F*	*p*	partial eta squared	Mean whole movie	SD whole movie	Mean hazard window	SD hazard window
3	32	30	12.5	.001	.294	49.320	9.097	55.406	9.415
5	33	31	5.380	.027	.148	50.316	9.069	54.414	12.032
7	36	34	8.119	.007	.193	47.031	11.772	51.398	14.785
13	36	34	5.744	.022	.145	49.474	10.716	48.803	11.102

The degrees of freedom for each movie is 1.

Table 5

Results for the main effects of attention comparing the attention score during the whole movie and when pressing the spacebar per movie.

Movie	*N*	df Error	*F*	*p*	partial eta squared	Mean whole movie	SD whole movie	Mean pressed	SD pressed
3	33	31	4.289	.047	.122	49.197	8.982	51.567	9.736
4	34	32	6.864	.013	.177	49.086	9.978	54.446	14.536
6	35	33	5.886	.021	.151	49.028	9.532	52.798	13.053
7	30	28	5.988	.021	.176	46.931	12.570	51.832	17.111
8	34	32	5.029	.032	.136	50.735	9.960	53.591	13.286
9	37	35	10.909	.002	.238	48.598	10.050	51.717	12.760
11	36	34	13.353	.001	.282	51.043	11.322	55.364	11.871

The degrees of freedom for each movie is 1.

7. Discussion study 2

The independent samples t-test comparing the hazard perception score between adults and adolescents was not significant. This finding implies that the adolescents and the adults have the same hazard perception skills, which is not in line with the hypothesis nor is it in line with the results from Elliot and Baughan (2003). They showed that adolescents aged 13 to 16 engage more in unsafe road behaviours than 11 to 12 year olds do. However, it is possible to be as good in perceiving danger as adults and nonetheless engage in risky behavior. The danger perception drop found by Granié (2009) is between seventh grade (12-13 year olds) and tenth grade (15-16 year olds), and the older children perceive the dangers less than the younger children. In that case, the secondary school students used in the present study could have been too young to have a danger perception drop.

The repeated measures ANOVA does not give consistent results. For the total Mean of attention in all films compared to the total Mean of the attention when pressed as well as compared to the total Mean of attention in the hazard window, main effects were found for the difference in attention both with medium effect sizes. This indicates that both groups have a higher attention score during the hazard perception window and when pressing than during the whole movie, showing that their attention was higher at those moments. However, when looking at each movie separately, about half of the movies do not show a difference in attention score, only one movie shows an interaction effect, and no movie shows an effect of age (adult versus adolescent). Besides, the effect sizes are also smaller when looking at each movie separately. This indicates that both groups have about half of the time a higher attention when confronted with a possible hazard. However, another explanation could be that the attention score of the Mindwave device is not able to discriminate between situations which are similar, but differ slightly in task difficulty. More studies should be conducted to investigate whether people already have high attention to their environment before reacting to a possible hazard, or EEG is not able to discriminate between such similar situations. As seen in study 1 but also in the study of Ryu and Myung (2005), the EEG output is not always able to distuinguish between different levels of difficulty. However, for movie 1 an interaction effect between age and attention was found however, with a small effect size. Movies 3, 5, 7 and 13 showed a maineffect for attention in the hazard window with a medium effect size for movie 3 and small effect sizes for the other movies. For movies 3, 4, 6, 7, 8, 9, and 11 a maineffect for attention was found when pressing, with medium effect sizes for movie 9 and 11 and small effect sizes for the other movies. A main effect of attention indicates that the

Mean attion score during the whole movie was different than the atttention score during the hazard window or when pressed.

Movie 1 shows an interaction effect of attention and age for the second hazard window of movie 1 and the whole movie, see appendix C for plots of all effects that were found. Adults have a lower attention score during the hazard window than during the whole movie, whereas the adolecents have a higher attention score during the hazard window than during the whole movie. A possible explanation for this finding could be that adults are experienced with the specific hazard shown in the movie and therefore do not need to give extra attention to it, while adolescents are not familiar woth the hazard shown in the movie and therefore focus a lot of attention on the possible hazard. Movies 3, 5, 7 and 13 show a main effect of attention where the hazard window has a higher Mean attention score than the whole movie, indicating that whether or not they pressed for the particular hazard, the attention of both groups was hightened during the visibility of the possible hazard. This, compared to what mentioned above, would argue that EEG measurements at least for some situations are able to distuinguish between lower attention needing environments and higher attention needing environments. Movies 3, 4, 6, 7, 8, 9, and 11 show a maineffect for attention when the attention level of the whole movie was compared to the moments when they pressed the space bar during the same movie. This indicates that the participants were paying more attention at the moment they pressed the space bar. However, this result is only found in half of the movies.

Nonetheless, since only about half of the movies speratley show an effect, more reearch is needed before any definite conclusion could be given to the cause of these findings. It could be that the movies in which a main effect of attention was found, the hazard was more obvious to the participants than in the other movies. However, it mostly remains unclear why these contrasting results are found therefore more research is needed to investigate this. For example, a distinction could be made between different types of hazards to see if this has an influence on the attention pattern. It should also be noted that in study 1 contrasting results were found, showing a higher attention score doing nothing than doing an arithmetic task. Therefore, no definite conclusions can be drawn from the results from the Mindwave device. Another proposal for future research is to look at other physiological measures such as the galvanic skin response. The galvanic skin response is sensitive to arousal and therefore might be useful to measure risk perception instead of hazard perception.

For the reaction times, no differences where found between adolescents and adults. Still no differences where found when the bonus for selecting the right screenshot was included. This shows that there is no difference in reaction time for both groups, which is in contrast with our hypothesis. It was expected that adolescents have longer reaction times towards possible hazards than adults, since their cognitive control system is not fully developed and their socioemotional system is more sensitive (Boyer, 2006; Steinberg, 2007). Therefore it was expected that adolescents only react at the moment the situation gets more dangerous and elicits an emotional response, which is later than when it is cognitively anticipted.

All results from study 2 combined suggest that adolescents are able to perceive all three levels of hazard perception as defined in Vlakveld (2014) as good as adults. Therefore it seems unlikely that the unsafe behaviours are due to problems with hazard perception. Study 2 shows that in all cases adolescents react the same way as adults do. However, some other factors than hazard perception could have (partly) caused the found results.

First, the secondary school students could have been primed by the word "danger" and because of it performed better (Hill, Lewis, & Dunbar, 2000). However, this study only included children in the age of 5 to 10 years and therefore, it is not known if the adolescents in the current sample were influenced by the word "danger". Future research should investigate the priming of words like "danger" in different age groups to prevent experiments to be influenced by it.

Second, the danger perception drop showed by Granié (2009) takes place at a later age period than the tested adolescents. Older participants might still show such a perception drop. More research is needed to investigate this.

Third, Elliott and Baughan (2003) show that adolescents are well aware of their dangerous behaviour, in combination with our results and other studies it is not likely that the risk behaviour in adolescents is due to a lack of hazard perception (Brijs, et al., 2009; Elliott & Baughan, 2003). More likely is the developing brain a cause for this behaviour. gains Maslowsky, Keating, Monk, and Schulenberg (2011) and Brijs et al. (2009) show that adolescents just as adults are more prone to short term gains than losses. In the present study, it probably was not perceived as a gain to engage in risky behaviour, however in real life it could be. Since adolescents do not have a fully developed cognitive system and have a sensitive socio-emotional system, this could cause their behaviour. However, to investigate this it would be helpful to test in more realistic settings. For example while cycling their normal route to school and back, that way you do not have a participant bias and really capture natural behaviour.

Fourth, a maximum of four times to press for a possible hazard was given which might have biased participants to press at least one time and being saving when already used two or three presses. Also some participants had difficulties with the space bar pressing two or three times really quickly at almost the same time, when they only wanted to press once, leaving them with no or less possibilities to indicate possible hazards for the rest of the movie.

Another factor that could have played a role was the students who were allowed to participate. Since they would miss class, only the top students were allowed to participate.
Future research could also look with an eye-tracker if the attention score is raised the moment they look first at the hazard independent if they press for the hazard.

All in all, the results from study 2 suggest that danger perception is not impaired in the age of 12 to 14. More realistic testing settings should be able to test whether this finding is only found in the lab and differs from the behavior in the real world or whether adolescents actually do not behave as risky as is found by self-report and observation studies (Leijenhorst, 2010).

8. Overall conclusion

Study 1 shows that in both the sitting condition and the physical activity condition the Mindwave device is able to distinguish between different tasks. However, the device is not able to distinguish between the two arithmetic tasks, suggesting that these tasks have the same task difficulty. Another EEG study also did not always find differences between task difficulties either (Ryu & Myung, 2005). A more surprising finding is the finding that in the sitting condition the attention score was lower during no task than during either arithmetic task. Therefore more research is needed to determine in more detail how good the Mindwave can be used for research. Possible when looking at the frequency bands, the Mindwave device does not show such contrasting results. Nonetheless, when only looking at the results from the present study it should be concluded that the Mindwave device is not usable for research settings.

Study 2 shows that in most cases, the adolescents react in the same way as the adults do. However, different factors could play a role in the current study. Nonetheless, in line with conclusions from other studies (Elliott & Baughan, 2003; Brijs, et al., 2009) it is most probable that adolescents do perceive danger and therefore this does not cause their risky behaviour. Some other explanations could be given to these risky behaviours and should be studied more in depth, such as sensitivity to shirt-term gains (Maslowsky, et al., 2011; Brijs, et al., 2009) in combination with a sensitive socio-emotional system and an immature cognitive control system (Brijs, et al., 2009; Steinberg, 2007). This conclusion suggests that the risky behaviour in adolescents is rather planned or impulsive than due to not perceiving the danger in it. It is also important to investigate risky behaviour in adolescents in more realistic settings, since the experimental setup of experiments in the lab could have an influence on the behaviour of the adolescent.

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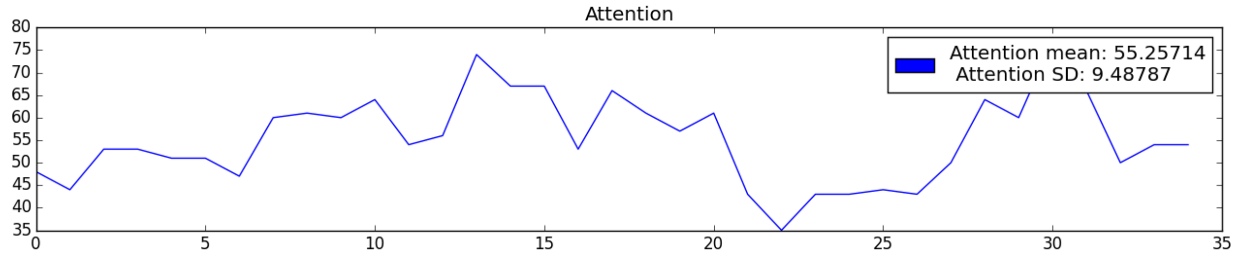
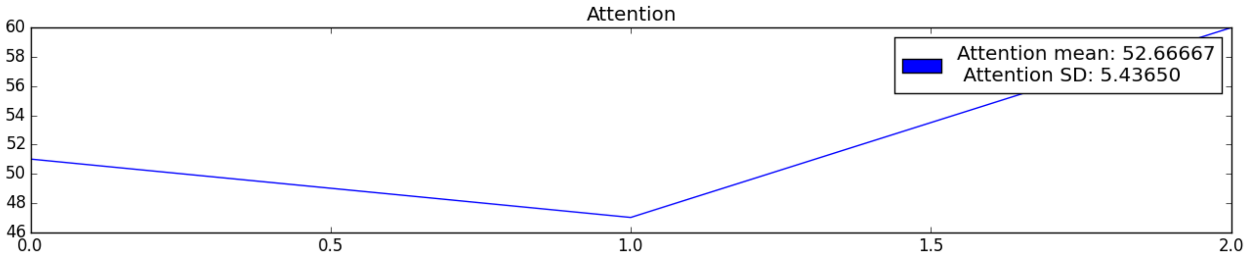
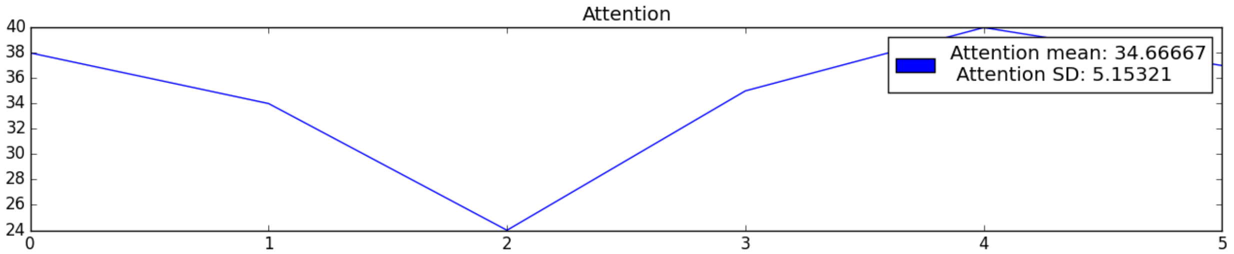
Appendix A



The attention score of a participant during one movie.



The attention score of the same participant for the first time he presses the space bar during one movie.



The attention score window of the same participant during the visibility of a hazard.

Appendix B

Movie 1 (adults (*N*=11), adolescents (*N*=23)) included two hazards, for the first hazard no maineffects of attention was found, *F*(1,32)=3.430, *p*=.073, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=.739, *p*=.396, and also no between-subjects effect of expertise was found, *F*(1,32)=.015, *p*=.902. For the second hazard of the first movie no maineffects of attention was found, *F*(1,32)=.526, *p*=.474, nor an between-subjects effect of expertise was found, *F*(1,32)=3.131, *p*=.086. However, an interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=5.849, *p*=.021, partial eta squared=.155. For the attention when pressed (adults (*N*=11), adolescents (*N*=21)), no main effect of attention was found, *F*(1,30)=.001, *p*=.973, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,30)=.031, *p*=.862, and also no between-subjects effect of expertise was found, *F*(1,30)=.347, *p*=.560.

Movie 2 (adults (*N*=11), adolescents (*N*=23)) also included two hazards. For the first hazard no main effect of attention was found, *F*(1,32)=.089, *p*=.767, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=.001, *p*=.971, and also no between-subjects effect of expertise was found, *F*(1,32)=.267, *p*=.609. For the second hazard of movie 2 no main effect of attention was found, *F*(1,32)=1.060, *p*=.311, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=.289, *p*=.594, and also no between-subjects effect of expertise was found, *F*(1,32)=.020, *p*=.889. For the attention when pressed (adults (*N*=10), adolescents (*N*=22)), no main effect of attention was found, *F*(1,30)=1.499, *p*=.230, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,30)=.131, *p*=.720, and also no between-subjects effect of expertise was found, *F*(1,30)=.267, *p*=.609.

Movie 3 has one hazard. For the hazard of movie 3 (adults (*N*=11), adolescents (*N*=21)), a main effect of attention was found, *F*(1,30)=12.5, *p*=.001, partial eta squared=.294. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,30)=3.645, *p*=.066, nor an between-subjects effect of expertise was found, *F*(1,30)=1.945, *p*=.173. For the attention when pressed (adults (*N*=11), adolescents (*N*=22)), a main effect of attention was found, *F*(1,31)=4.289, *p*=.047, partial eta squared=.122. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,31)=.515, *p*=.478, nor an between-subjects effect of expertise was found, *F*(1,31)=.008, *p*=.930.

For the only hazard of movie 4 (adults (*N*=10), adolescents (*N*=22)), no main effect of attention was found, *F*(1,30)=1.516, *p*=.228, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,30)=3.468, *p*=.072, and also no between-subjects effect of expertise was found, *F*(1,30)=2.206, *p*=.148. For the attention when pressed (adults (*N*=11), adolescents (*N*=23)), a main effect of attention was found, *F*(1,32)=6.864, *p*=.013, partial eta squared=.177. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=1.204, *p*=.281, nor an between-subjects effect of expertise was found, *F*(1,32)=1.135, *p*=.295.

For the hazard of movie 5 (adults (*N*=11), adolescents (*N*=22)), a main effect of attention was found, *F*(1,31)=5.380, *p*=.027, partial eta squared=.148. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,31)=.065, *p*=.801, nor an between-subjects effect of expertise was found, *F*(1,31)=.051, *p*=.823. For the attention when pressed (adults (*N*=10), adolescents (*N*=20)), no main effect of attention was found, *F*(1,28)=1.768, *p*=.194, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,28)=.348, *p*=.560, and also no between-subjects effect of expertise was found, *F*(1,28)=.684, *p*=.415.

For the hazard in movie 6 (adults (*N*=11), adolescents (*N*=24)), no main effect of attention was found, *F*(1,33)=3.572, *p*=.068, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,33)=.833, *p*=.368, and also no between-subjects effect of expertise was found, *F*(1,33)=1.406, *p*=.244. For the attention when pressed (adults (*N*=11), adolescents (*N*=24)), a main effect of attention was found, *F*(1,33)=5.886, *p*=.021, partial eta squared= .151. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,33)=.009, *p*=.925, nor an between-subjects effect of expertise was found, *F*(1,33)=.622, *p*=.436.

For the hazard of movie 7 (adults (*N*=12), adolescents (*N*=24)), a main effect of attention was found, *F*(1,34)=8.119, *p*=.007, partial eta squared=.193. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=<.001, *p*=.987, nor an between-subjects effect of expertise was found, *F*(1,34)=.293, *p*=.592. For the attention when pressed (adults (*N*=12), adolescents (*N*=18)), a main effect of attention was found, *F*(1,28)=5.988, *p*=.021, partial eta squared= .176. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,28)=.001, *p*=.972, nor an between-subjects effect of expertise was found, *F*(1,28)=.318, *p*=.577.

For the hazard in movie 8 (adults (*N*=12), adolescents (*N*=24)), no main effect of attention was found, *F*(1,34)=1.509, *p*=.228, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=1.249, *p*=.272, and also no between-subjects effect of expertise was found, *F*(1,34)=.479, *p*=.493. For the attention when pressed (adults (*N*=12), adolescents (*N*=22)), a main effect of attention was found, *F*(1,32)=5.029, *p*=.032, partial eta squared= .136. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=.018, *p*=.893, nor an between-subjects effect of expertise was found, *F*(1,32)=.064, *p*=.801.

Movie 9 (adults (*N*=12), adolescents (*N*=25)) included two hazards, for the first hazard no main effect of attention was found, *F*(1,35)=2.421, *p*=.129, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,35)=1.790, *p*=.190, and also no between-subjects effect of expertise was found, *F*(1,35)=.404, *p*=.529. For the second hazard of movie 9, no main effect of attention was found, *F*(1,35)=2.896, *p*=.098, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,35)=.059, *p*=.809, and also no between-subjects effect of expertise was found, *F*(1,35)=.005, *p*=.945. For the attention when pressed (adults (*N*=12), adolescents (*N*=25)), a main effect of attention was found, *F*(1,35)=10.909, *p*=.002, partial eta squared= .238. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,35)=.424, *p*=.519, nor an between-subjects effect of expertise was found, *F*(1,35)=.001, *p*=.974.

For the hazard in movie 10 (adults (*N*=12), adolescents (*N*=24)), no main effect of attention was found, *F*(1,34)=3.558, *p*=.068, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=.215, *p*=.646, and also no between-subjects effect of expertise was found, *F*(1,34)=1.457, *p*=.236. For the attention when pressed (adults (*N*=12), adolescents (*N*=24)), no main effect of attention was found, *F*(1,34)=1.667, *p*=.205, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=.028, *p*=.868, and also no between-subjects effect of expertise was found, *F*(1,34)=2.218, *p*=.146.

For the hazard in movie 11 (adults (*N*=12), adolescents (*N*=23)), no main effect of attention was found, *F*(1,33)=.014, *p*=.906, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,33)=.445, *p*=.509, and also no between-subjects effect of expertise was found, *F*(1,33)=1.315, *p*=.260. For the attention when pressed (adults (*N*=12), adolescents (*N*=24)), a main effect of attention was found, *F*(1,34)=13.353, *p*=.001, partial eta squared= .282. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=.186, *p*=.669, nor an between-subjects effect of expertise was found, *F*(1,34)=1.000, *p*=.324.

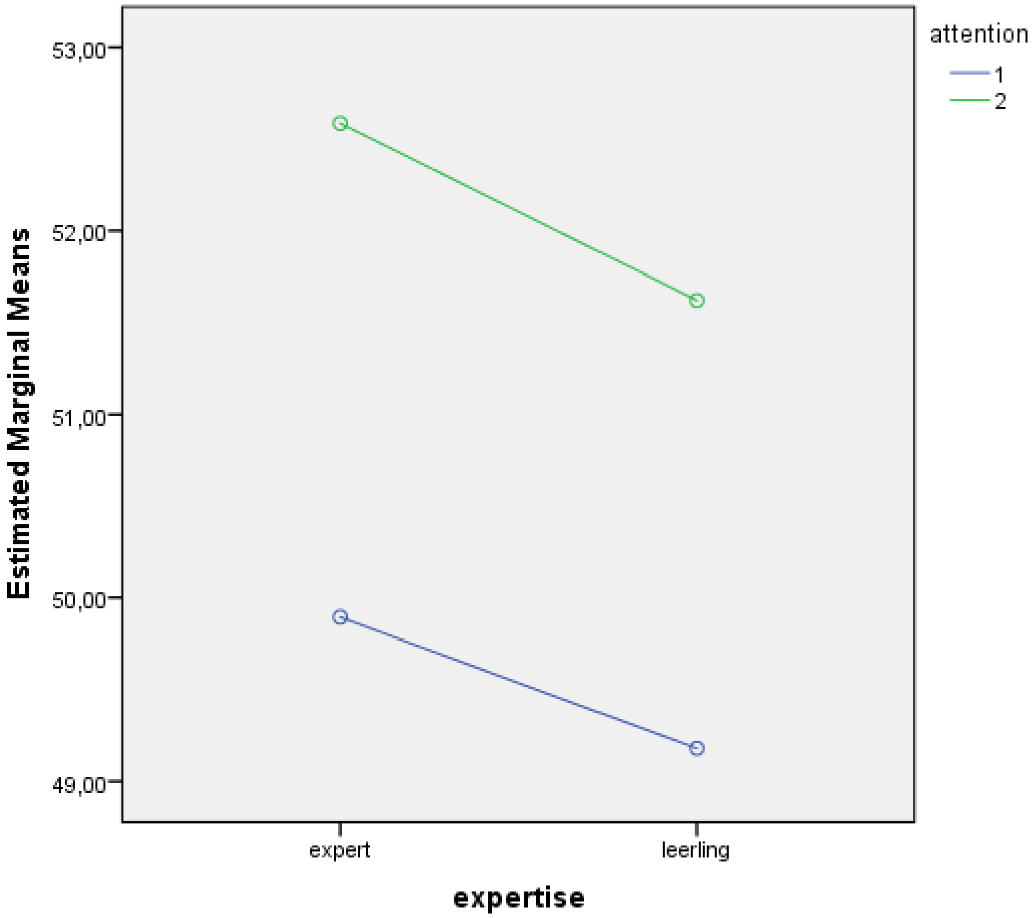
For the hazard in movie 12 (adults (*N*=12), adolescents (*N*=23)), no main effect of attention was found, *F*(1,33)=.247, *p*=.623, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,33)=.076, *p*=.785, and also no between-subjects effect of expertise was found, *F*(1,33)<.001, *p*=.986. For the attention when pressed (adults (*N*=12), adolescents (*N*=23)), no main effect of attention was found, *F*(1,33)=2.343, *p*=.135, nor an interaction effect of attention and age (adult or adolescent) was found, *F*(1,33)=.018, *p*=.894, and also no between-subjects effect of expertise was found, *F*(1,33)=.129, *p*=.721.

For the hazard of movie 13 (adults (*N*=12), adolescents (*N*=24)), a main effect of attention was found, *F*(1,34)=5.744, *p*=.022, partial eta squared=.145. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,34)=.065, *p*=.800, nor an between-subjects effect of expertise was found, *F*(1,34)=.427, *p*=.518. For the attention when pressed (adults (*N*=12), adolescents (*N*=22)), no main effect of attention was found, *F*(1,32)=.007, *p*=.935. No interaction effect of attention and age (adult or adolescent) was found, *F*(1,32)=.095, *p*=.760, nor an between-subjects effect of expertise was found, *F*(1,32)=.380, *p*=.542.

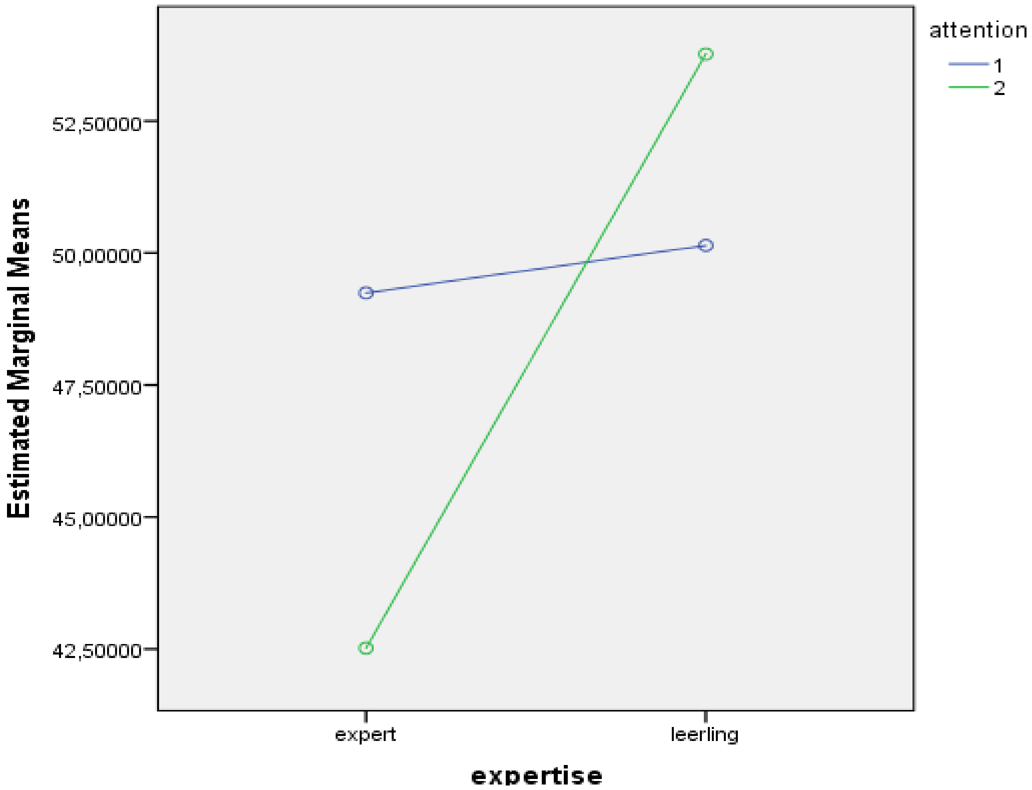
Appendix C

For all plots, expertise is the age, where 'expert' indicates the adults and 'leerling' indicates the secondary school students. Attention 1 is always the Mean attention score of the whole film and attention 2 is the Mean attention score of the hazard window or when pressed.

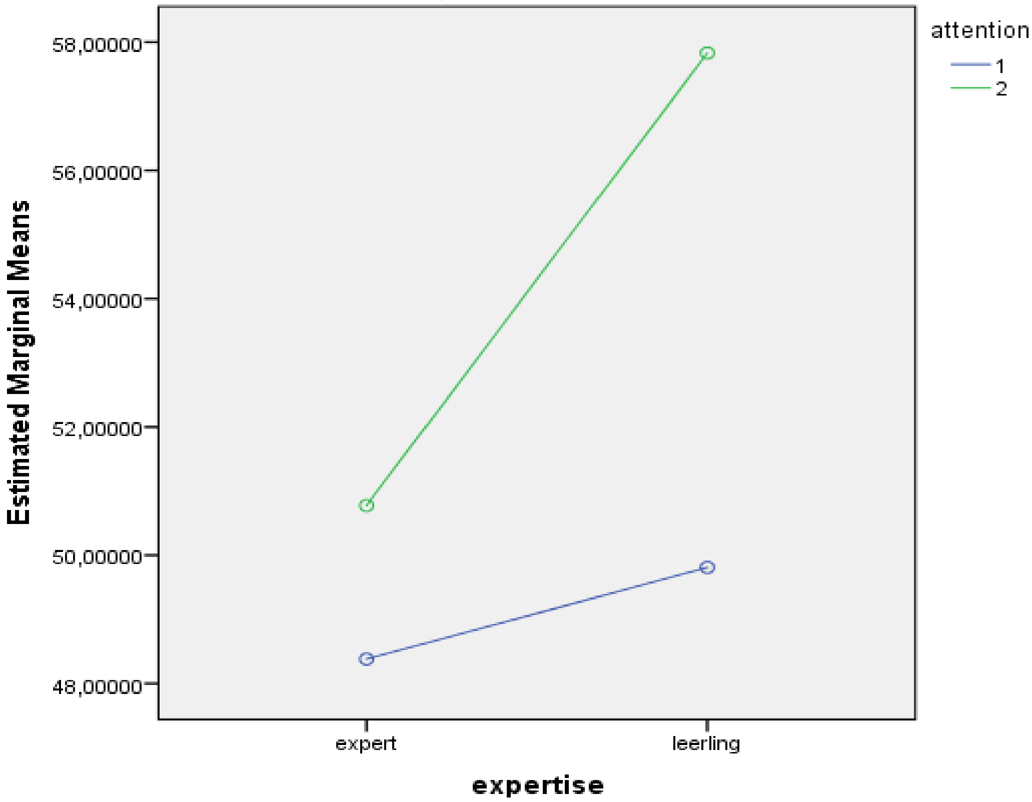
Main effect of attention for the total Mean attention score during the whole movie compared to the total Mean attention score during all presses on the spacebar.



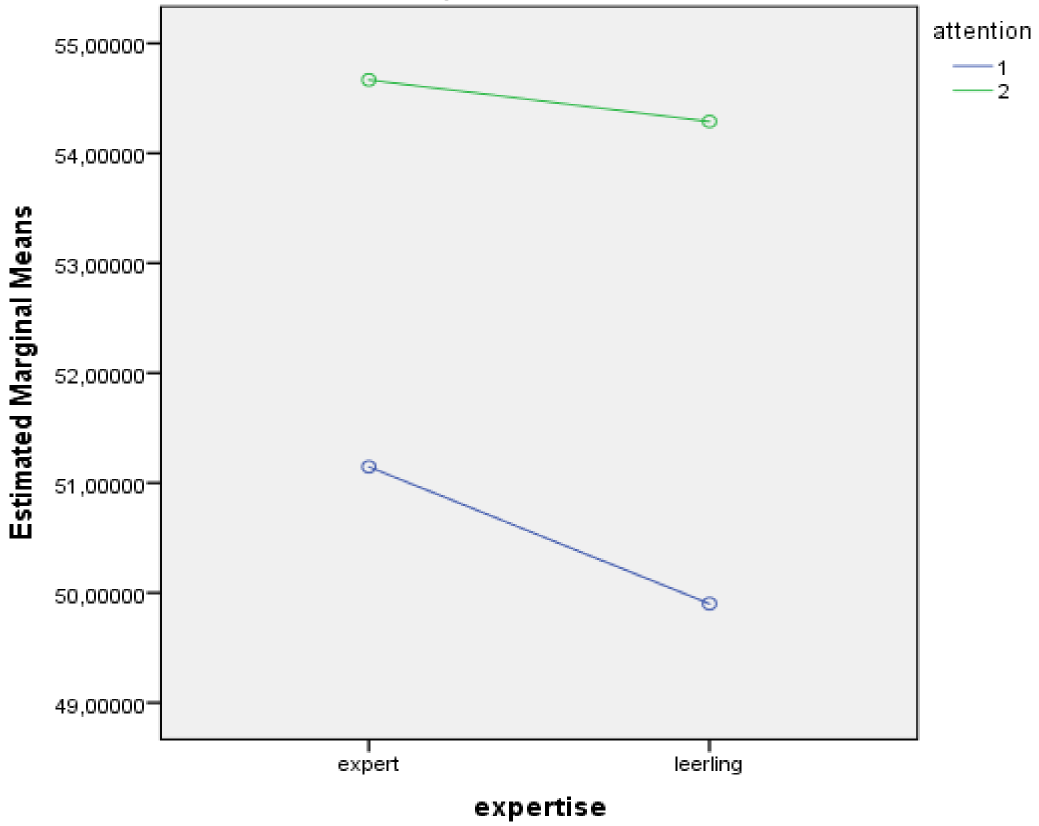
Plot of the interaction effect of age and attention score when comparing the Mean attention score in movie 1 with the Mean attention score during the second hazard window of movie 1.



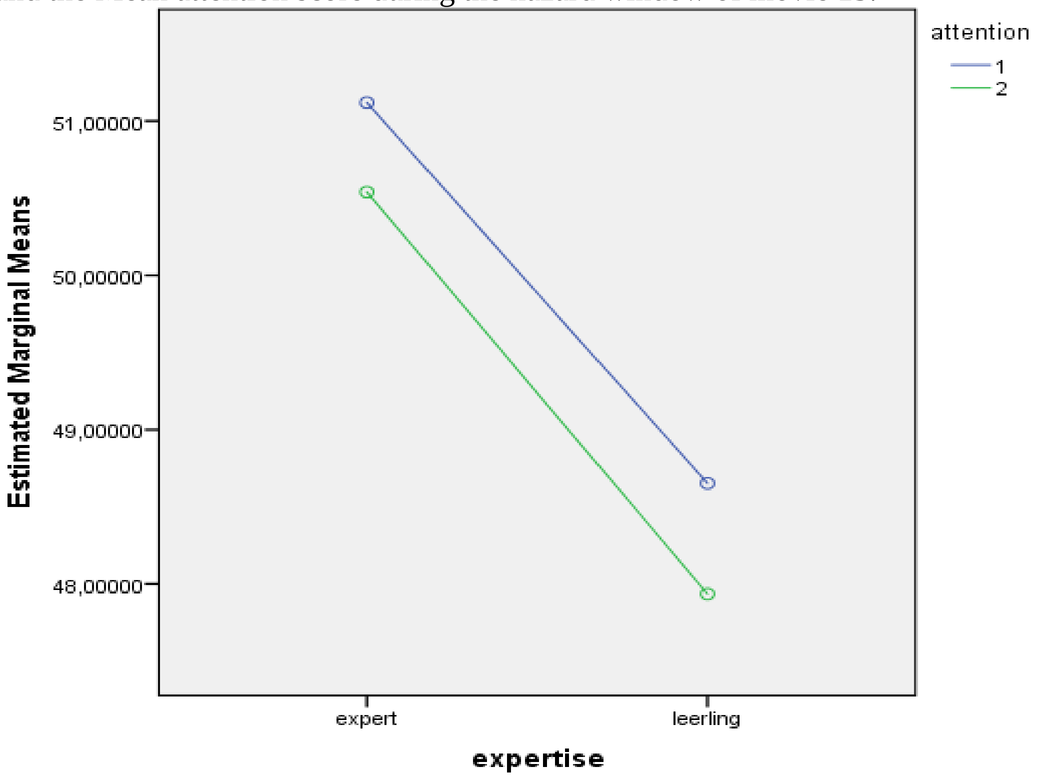
Plot of the main effect of attention when comparing the Mean attention score during movie 3 and the Mean attention score during the hazard window of movie 3.



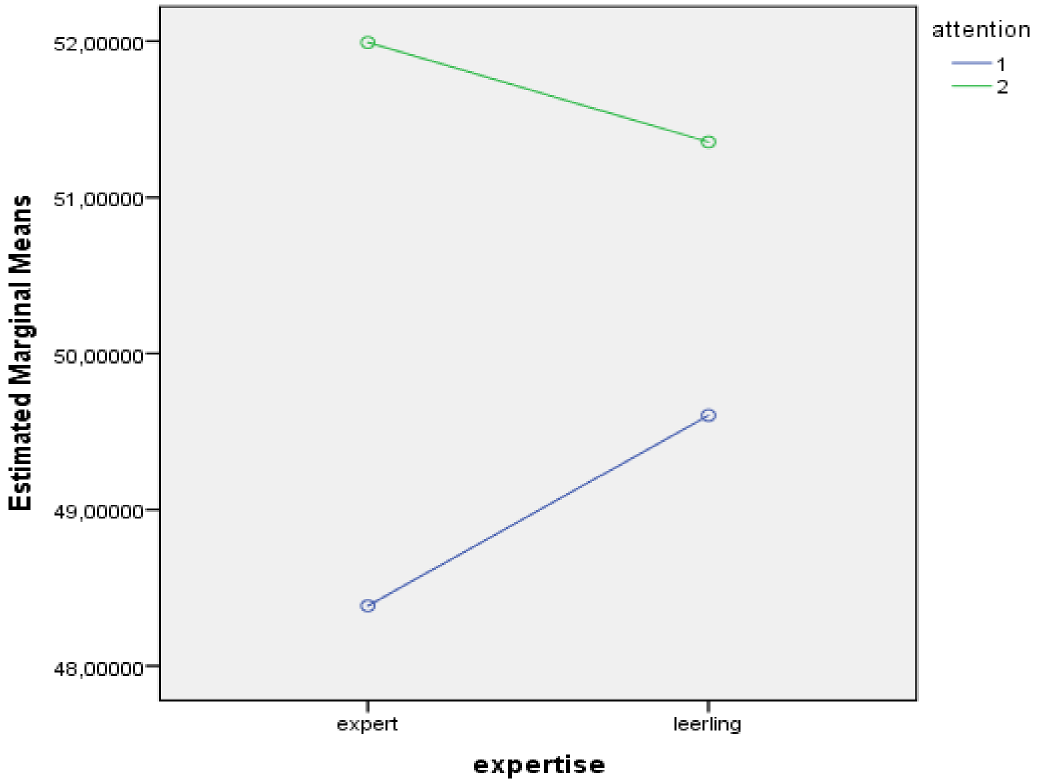
Plot of the main effect of attention when comparing the Mean attention score during movie 5 and the Mean attention score during the hazard window of movie 5.



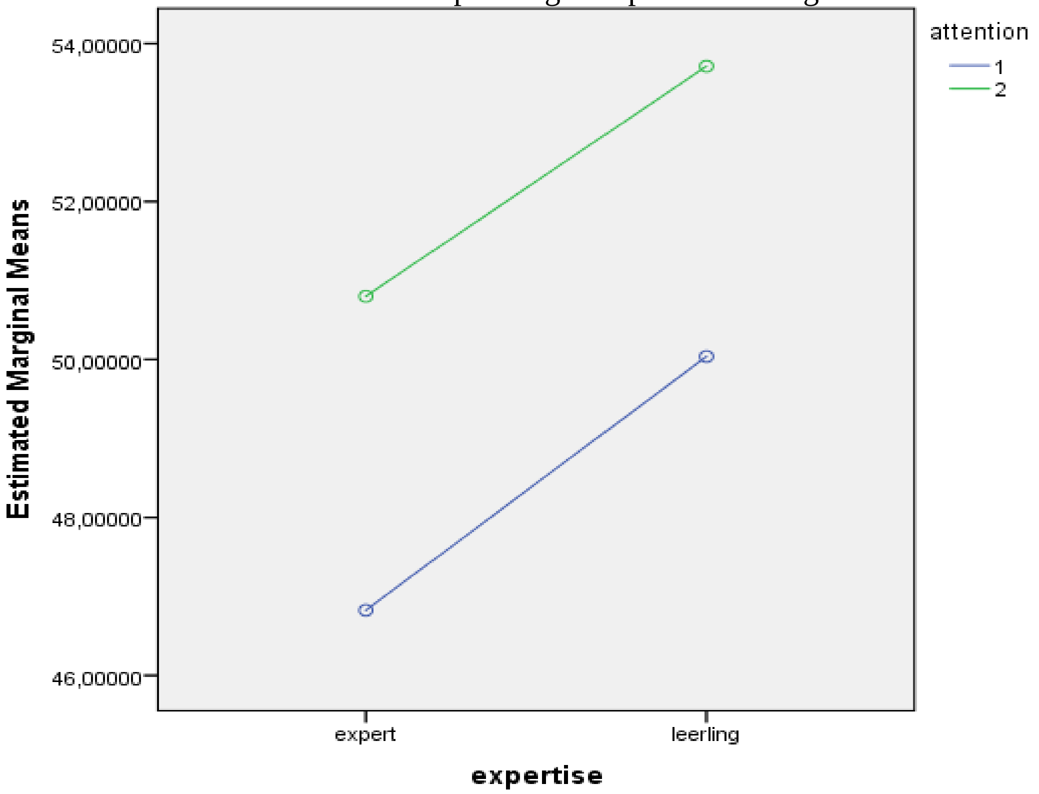
Plot of the main effect of attention when comparing the Mean attention score during movie 13 and the Mean attention score during the hazard window of movie 13.



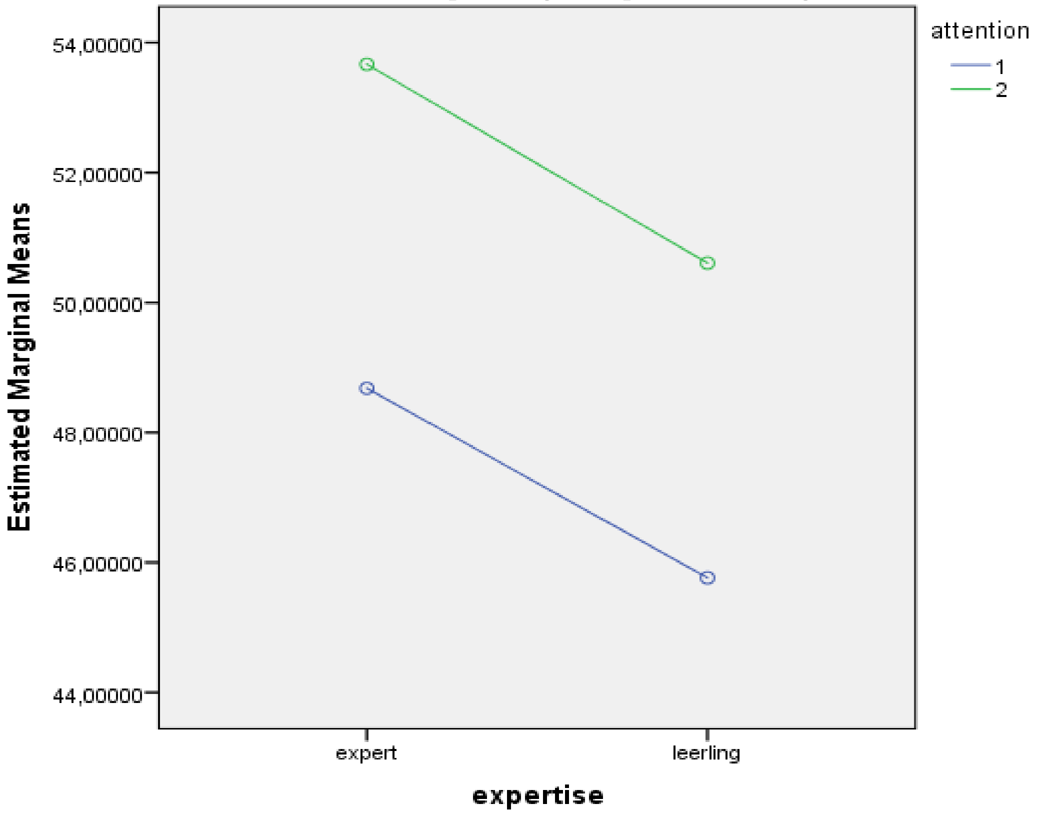
Plot of the main effect of attention when comparing the Mean attention score during movie 3 and the Mean attention score when pressing the spacebar during movie 3.



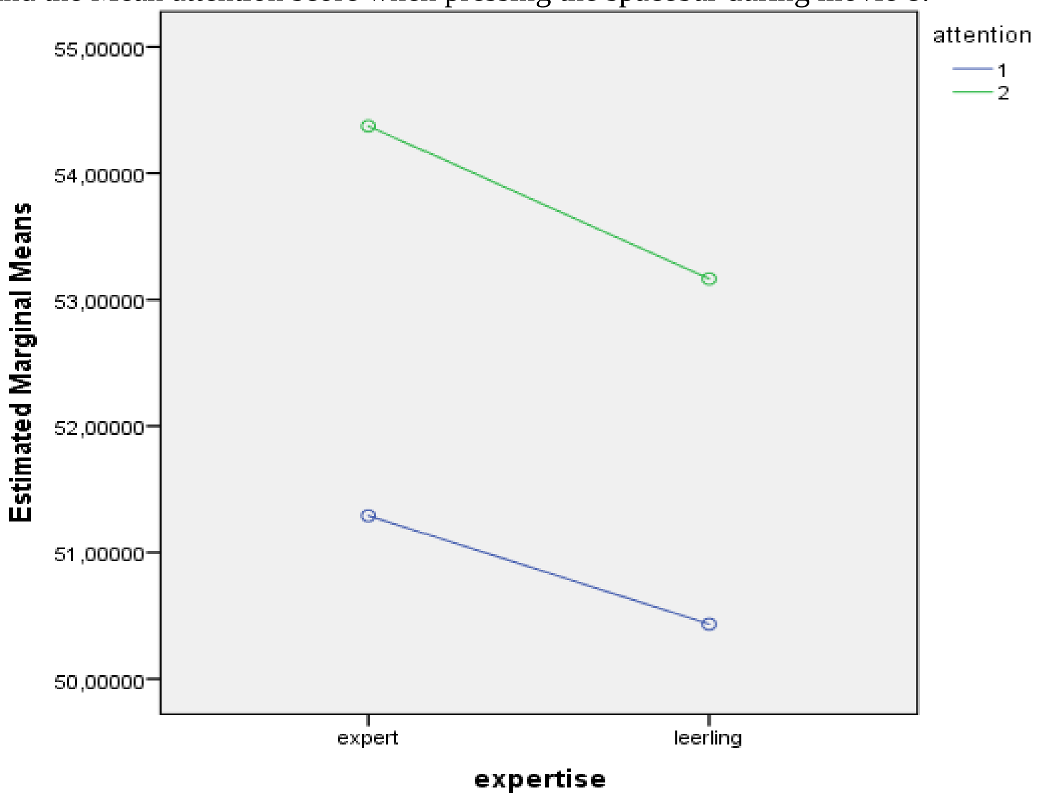
Plot of the main effect of attention when comparing the Mean attention score during movie 6 and the Mean attention score when pressing the spacebar during movie 6.



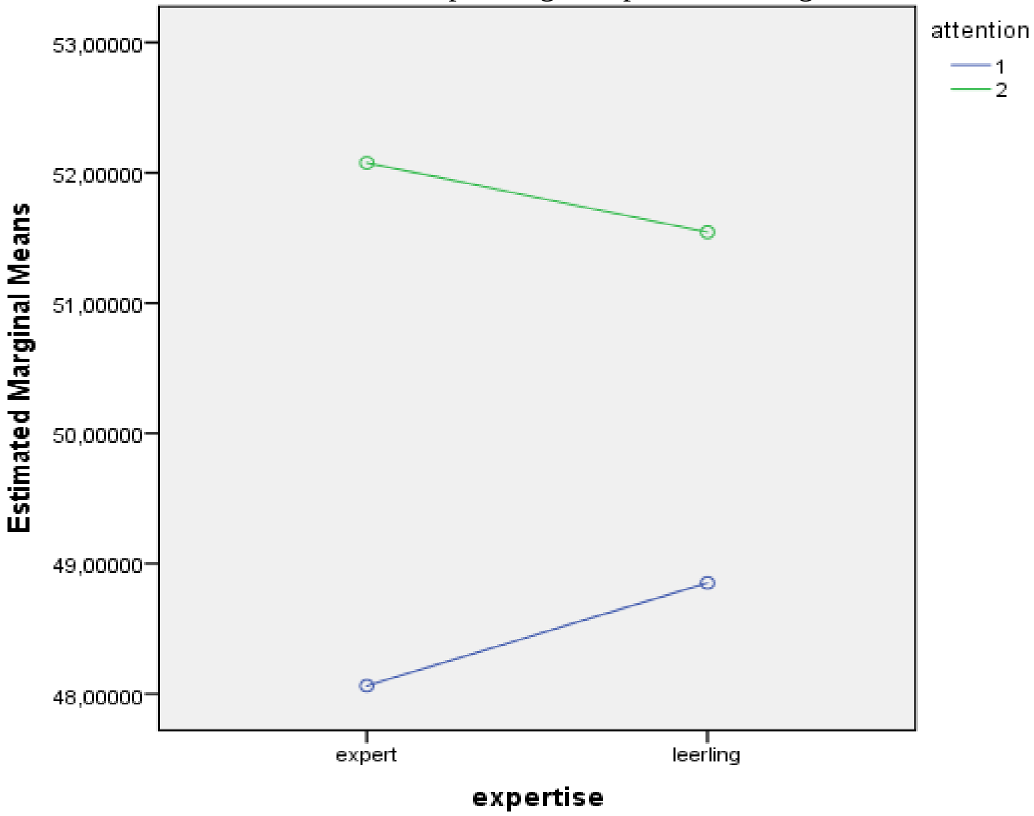
Plot of the main effect of attention when comparing the Mean attention score during movie 7 and the Mean attention score when pressing the spacebar during movie 7.



Plot of the main effect of attention when comparing the Mean attention score during movie 8 and the Mean attention score when pressing the spacebar during movie 8.



Plot of the main effect of attention when comparing the Mean attention score during movie 9 and the Mean attention score when pressing the spacebar during movie 9.



Plot of the main effect of attention when comparing the Mean attention score during movie 11 and the Mean attention score when pressing the spacebar during movie 11.