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The effects of implementing the ‘FireFlies V2’ system in a secondary school classroom on teachers and students

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Abstract

In this research, a new classroom technology is presented. The design of this technology is based on earlier research about design for peripheral interaction and secondary school teachers' routines. The purpose of designing technologies for peripheral interaction, is that they can be more fluently embedded into peoples' routines, by requiring fewer mental resources than technologies that do not enable peripheral interaction. The designed system is called 'FireFlies V2' and its purpose is to give secondary school teachers awareness about their attention distribution. The effects of implementing the FireFlies V2 system in a secondary school classroom on teachers and students were studied. Ten secondary school teachers participated in this research, by using the system FireFlies V2 during two of their lessons. During another two lessons, the FireFlies were not implemented and the teacher was only being tracked. At the end of all of the lessons, both the teachers and the students filled out a questionnaire that was put together by the researchers and the teachers were interviewed. This paper discusses the quantitative results, which indicate that the sample of teachers was probably too small to find significant results: The FireFlies V2 system did not affect the teacher's self-reports about awareness, satisfaction and mental effort. Also their division of presence over the front and back of the classroom was not influenced by the system. However, the testing of a new technology with experimental methods hasn't been done before and further exploration and improvement in future research would be interesting.

Human-computer interaction is a research field in which the interaction of humans with computers is observed and new technologies that enable novel ways of interaction with computers are designed. It is a very innovative field which anticipates the fast-moving digitalization the world is undergoing today. Many disciplines come together in the research and application of human-computer interaction. This paper will focus on the multidisciplinary approach to the exploration of a novel technology, combining the fields of industrial design and cognitive psychology.

Bakker (2013) states that traditional methods of human-computer interaction require focused attention during interaction. For example, interaction with a smartphone or computer practically always requires focused attention. The requirement of focused attention can be

problematic when the aim is to fluently embed computing technologies in people's everyday routines (Bakker, 2013). For example, interacting with a smartphone is not easily combined with other daily tasks such as driving a car. This problem is a current field of interest in the area of industrial design.

Design for peripheral interaction

As a solution, Bakker (2013) proposes 'design for peripheral interaction', defined as: "interaction with computing technology which can take place in the periphery of attention and shift to the center of attention when relevant for or desired by the user". Within this context, attention is defined as the division of mental resources over potential activities. At the center of attention is the activity to which most resources are allocated. All remaining potential activities reside in the 'periphery' of attention (Bakker, 2013). Peripheral interaction should not be confused with peripheral vision; it is not necessarily about the physical periphery of vision but more so about the attentional 'periphery'. The aim of designing technology for peripheral interaction is for the technology to become an integrated and meaningful part of people's everyday lives and routines (Bakker, 2013).

Design for peripheral interaction is closely linked to cognitive theories: Similar to Bakker's (2013) definition, in cognitive psychology it is common to refer to attention as the allocation of limited processing resources (Anderson, 2015). These mental- and processing resources that Bakker (2013) and Anderson (2015) mention, are requirements for performing cognitive tasks like interacting with technology. These cognitive tasks are generally executed by the working memory, which is a limited capacity system (Baddeley, 2003). Consequently, it is possible that a situation or combination of cognitive tasks requires too much mental resources, causing people to experience 'cognitive overload' (Sweller, 1988). Therefore, it is valuable to develop technologies that enable interaction in the periphery of attention, and as a result require fewer mental resources for interaction.

Teaching

The concepts of cognitive load and peripheral interaction are useful for understanding and assisting teaching activities respectively (Feldon, 2007; Bakker, 2013). Teachers have very busy routines and are especially vulnerable to experiencing cognitive overload (Feldon, 2007). However, most technologies that are developed for classroom settings, such as

smartboards, require interaction in the center of people's attention and consequently extra mental resources (Bakker, van den Hoven, & Eggen, 2014). Therefore, there are great opportunities for developing classroom technologies that enable peripheral interaction, which could be embedded more fluently into the teacher's busy routines.

Design for peripheral interaction applied to teaching

Bakker, Van den Hoven, & Eggen (2014) studied these opportunities and presented three case studies. In all of the case studies, a technology that resides in the periphery of attention was implemented in a primary school classroom setting. The case studies that Bakker et al. (2014) present were explored through a research-through-design approach. This means that the prototypes should not be seen as finished products, but rather as tools for exploring the possibilities of design for peripheral interaction. Of the three case studies, the best example of design for peripheral interaction is the third case study that concerns the so-called 'FireFlies', which is also most elaborately explained in the study (Bakker et al., 2014).

The 'FireFlies' technology as designed by Bakker et al. (2014) consisted of light-objects that were placed on each student's desk, matching soundscapes and a teacher tool. The design was intended to support multiple tasks of the teachers, but it was an open-ended design: The teachers could decide for themselves for which goals and at which moments they wanted to use the system. The teacher could set the colors of the light-objects and thereby the soundscapes through interactions with the teacher tool. The teacher tool could be attached to the teacher's outfit and as a result carried around the classroom quite easily. The teacher tool was designed in such a way that the device could be interacted with using touch: The interactions with the teacher tool were intended to be quick and easy. The FireFlies system was deployed in four primary school classrooms for six weeks.

The results follow from evaluations formal and informal video analyses and interviews with teachers and students, of all three case studies combined. Two main characteristics of peripheral interaction and considerations for further research are presented. The first important characteristic is that the interactive systems frequently shift between the center and periphery of attention. Such shifts highly depend on the context and routines in which the interaction takes place, which demonstrates the second important characteristic: Peripheral interaction has a highly personal nature. The context and routines of the teachers influenced when interaction took place in the periphery or center of attention. Therefore, future design

for peripheral interaction can benefit from taking context and routine into account (Bakker et al., 2014).

Teaching routines and conclusions

To provide more insight in this regard, An, Bakker, & Eggen (2016) conducted a study to explore the routines of secondary school teachers. Stimulated recall interviews and group sessions with secondary school teachers resulted in important conclusions regarding their routines. Most importantly, there are a lot of complex tasks that secondary school teachers have to fulfill. As a result, the teachers often find themselves in situations where multitasking is required. A lot of the tasks that teachers have to do, involve reflection: The teachers have to check if they fulfill their goals and then adjust their teaching behavior accordingly. Based on this, An et al. (2016) suggest the design opportunity of presenting more information to teachers in an unobtrusive and ignorable way, so that the teachers do not have to reflect to obtain this information.

To link the findings of An et al. (2016) to a cognitive perspective again: Reflective tasks like An et al. (2016) describe are executed by working memory (Baddeley, 2003). As mentioned before, working memory is a limited capacity system and especially teachers are vulnerable to experiencing cognitive overload (Feldon, 2007; Sweller, 1988).

If a classroom technology presents information in such a way that it does not bring extra cognitive load (if it is designed for peripheral interaction (Bakker, 2013)), it might even lower the cognitive load the teachers experience. This is suggested by the perspective of distributed cognition: “the organization of mind is an emergent property of interactions among internal and external resources” (Hollan, Hutchins, & Kirsch, 2000, pp. 177). In other words, external resources (a potential classroom technology, displaying information) can become elements of the cognitive system itself (Hollan et al., 2000). The classroom technology would then take over cognitive tasks of the teacher, namely reflecting on certain actions, by displaying information about these actions. In this way the technology could lower the teacher’s cognitive load.

The conclusions from the study of An et al. (2016) and previous findings regarding design for peripheral interaction (Bakker, 2013; Bakker, et al., 2014) were motivation for the design of a new classroom technology for secondary schools. It was decided to develop a technology that was aimed at relieving a specific reflective task of the teacher, namely the teacher’s reflection on their attention distribution. It is important to note that in this case, the

term ‘attention’ is used to simply describe the time that teachers spend with students to assist them. An important review in the field of educational research found that a teacher’s proximity to students is very important (Gunter, Shores, Jack, Rasmussen, & Flowers, 1995), this is further support for the need for a system like the proposed technology: The ‘FireFlies V2’ system.

The FireFlies V2 system

The FireFlies V2 system consists of a self-developed tracker that is attached to a garment that the teacher can wear (see Figure 1) and displays feedback about this tracking information in the ‘FireFlies’, which are lighting objects that are placed throughout the classroom (see Figure 1). These lighting objects are slightly different from the ones used in the study of Bakker et al. (2014), but have the same distributed characteristic: They are embedded in the environment. The feedback is visualized through color changes: In the beginning of the lesson each FireFly is yellow and as the teacher spends more time around a certain FireFly, its color will gradually shift towards green. This color spectrum was selected because it was most feasible with the technology that was available, while assigning as little additional meaning to it as possible: It was not intended for the FireFlies V2 to judge a teacher’s behavior, the system merely aims to give a teacher better awareness of their behavior. It is then up to the teacher to use the information that is presented to them to adjust their behavior - if they find it necessary.

The FireFlies V2 system can be described as design for peripheral interaction because the teacher does not need to perform any additional focused action during their standard routines to interact with the FireFlies. The FireFlies are embedded in the environment and perceived at a glance while the teacher is looking around the classroom, which is also the most common side task discovered in the study by An et al. (2016). Influencing the FireFlies also happens during the teacher’s standard behavior: They walk around the classroom to assist students and consequently the FireFlies change color. As a result of enabling peripheral interaction, the FireFlies require less mental resources.

Figure 1. The FireFlies V2 system deployed in a secondary school classroom in Eindhoven. The teacher is wearing the tracking device and the lighting objects are placed throughout the classroom.

The FireFlies V2 system is intended to assist secondary school teachers in a number of ways. These are based on the multitasking nature of teaching (An, et al., 2016), the tendency for teachers to experience cognitive overload (Feldon, 2007), and the positive effects of a teacher's proximity on students (Gunter, et al., 1995). First of all, the system can provide awareness for the teacher by providing real-time feedback about their presence in the classroom. This awareness can influence the teacher's behavior: making them spread their presence more evenly throughout the classroom, which is beneficial for students (Gunter, et al., 1995). Both the teacher's and students' subjective experience of the teacher's division of attention can be positively influenced by this change in behavior. Finally, the feedback information that FireFlies V2 provides can also function as an external part of the teacher's working memory (Hollan, et al., 2000): By giving information, the teacher has to reflect less on their attention distribution (An, et al., 2016). In this way, the FireFlies could even offload the teacher's cognition (Hollan, et al., 2000).

The study

In this study, these potential effects of FireFlies V2 will be tested by implementing the system in secondary school classrooms. Hypotheses from both fields of interest, design and cognitive science, will be tested. The main research question is: How does the FireFlies V2 system affect both secondary school teachers and their students? The following sub-questions are a further specification:

1. How does the FireFlies V2 system affect the teachers' awareness of their distribution of attention over students?
2. What is the effect of the implementation of FireFlies V2 on the teachers' movement through the classroom?
3. How does the FireFlies V2 system affect the teachers' satisfaction of their distribution of attention over students?
4. What is the effect of the implementation of FireFlies V2 on the cognitive load that secondary school teachers experience when distributing their attention over students?
5. How does implementing FireFlies V2 affect the students' experience of the attention they receive from their teacher?
6. To what extent is the implementation of FireFlies V2 a distraction for students?

As mentioned before, these questions will be studied by implementing the FireFlies V2 system in secondary school classrooms. Previous systems that were designed for interaction in the periphery of attention were researched by placing the systems in a primary school classroom settings for a prolonged time and analyzing observations and interviews qualitatively (Bakker et al., 2014). This is standard practice in the design paradigm, but as a result not much can be said about the direct influences these systems have on the teachers and students that experience them: The situation where the system is implemented in the classroom is not being compared to a control condition.

To enable the studying of actual effects, FireFlies V2 will be studied using a field experiment. In this way, combining qualitative analysis with quantitative analysis, the aim is to gain insightful new considerations for design for peripheral interaction and present the effects the system FireFlies V2 has on both teachers and students. This paper will focus on the latter, and describe the quantitative data.

The hypotheses for the effects FireFlies V2 will have on teachers are that the system will make the teacher more aware of their attention distribution, as this is the purpose of the system. The second part of this hypothesis is that the awareness causes the teachers to spread

their presence more evenly over the classroom. Consequently, it is expected that the teacher will be more satisfied with their attention distribution when the FireFlies V2 system is implemented. Furthermore, the system is expected to lower the teacher's experience of cognitive load, by relieving the teacher's working memory's reflective task of remembering what students they have already given attention (Baddeley, 2003; Hollan, et al., 2000).

Hypotheses regarding the students are that more students will feel like they received the attention they needed from the teacher during lessons in which FireFlies V2 is implemented, because, again, this is the purpose of the system. During the development of FireFlies V2, some concerns were expressed regarding the distraction the system might cause for students: It is expected that a logical result of placing the FireFlies V2 system throughout the classroom is that the students will be more distracted when the system is implemented.

Methods

Participants

The participants were ten secondary school teachers and their students, from four different secondary schools in the Netherlands. Two of those schools were situated in Eindhoven, one in Tilburg and one in Roermond. Every teacher was tracked for four lessons. Sometimes the same students experienced multiple lessons (both control and experimental) and sometimes there were different students for different lessons. It was not feasible to control for this, because of the regularly changing schedules of secondary school teachers. As a result, also the number of students in the lesson varied from 11 to 32 (M=21,05, SD=4,40), a complete overview of this can be found in table 1. The teachers all taught different subjects. Their teaching experience varied from 3 to 32 years (M=13,95, SD=8,78), the complete overview of teaching experience can also be found in table 1.

The recruitment of participants mostly happened through e-mail. The recruitment e-mail and accompanying flyer can be found in Appendix 2.

Table 1.

The number of students that were present during the lessons that were used for the experiment, and the teachers' experience of teaching in years.

Teacher	School	Teaching experience in years	Amount of students in first lesson of experimental condition	Amount of students in second lesson of experimental condition	Amount of students in first lesson of control condition	Amount of students in second lesson control condition
1	1	8	20	20	19	23
2	1	17	29	27	27	26
3	2	32	21	21	20	19
4	2	8	18	16	19	17
5	2	17	15	17	18	14
6	2	3	21	14	11	17
7	3	13	23	28	27	24
8	3	4,5	27	21	22	19
9	4	12	19	24	26	15
10	4	25	25	25	24	25

Materials

The FireFlies V2 system is explained in the introduction, but some specifications are presented here. As mentioned before, the color of the light-objects (FireFlies) gradually changes from yellow to green. The total shift has nine steps; there are nine color gradations from yellow to green. A FireFly's color will change to the next color when the teacher spends enough time in the vicinity of this FireFly: The detection range is a 'box' around the FireFly which is 2.6 by 2.6 meters. When the teacher is in this detection range and he or she faces the FireFly (the FireFly is within the 90-degree facial direction angle), it takes fifty-five seconds before the color changes from one color gradation to the next. Therefore it takes fifty-five times eight seconds to reach the final color (bright green): 440 seconds. When the FireFly is within the detection range and in front of the teacher but outside the facial direction angle, it takes 110 seconds to level-up. When the FireFly is within the detection range but behind the teacher, it takes 220 seconds to level-up. These time indications were decided based on informal observations of previously obtained video material of secondary school lessons.

Data for the measurements of the quantitative part of this study consisted of the tracking data and responses to questionnaires that both the teacher and the students

completed. The tracking data consisted of the room coordinates which the teachers visited, which were recorded every two seconds.

The questionnaire that the teachers received after every lesson consisted of four items. The first two items were questions regarding the mental effort that the teachers experienced during the previous lesson. Specifically, the mental effort that the teachers experienced when reflecting on their attention distribution and the mental effort that the teachers experienced when distributing their attention. It was decided to specify the situations in which the teachers experience mental effort, because the FireFlies V2 system is also intended to assist in specifically these situations.

Paas, Tuovinen, Tabbers, & Van Gerven (2003) found that reliable measures of the subjective experience of cognitive load can be obtained with unidimensional scales. Moreover, they reported that such scales are sensitive to relatively small differences in cognitive load and that they are valid, reliable, and not intrusive. For this research, it was decided to use the Rating Scale Mental Effort (RSME) (Zijlstra, 2003). The RSME (Zijlstra, 2003) is basically a vertical line - with reference points - that's 150 millimeters long. The teachers mark on the vertical line how much mental effort they experienced and it is then measured how many millimeters from the bottom the teachers placed the mark.

The next two items on the teachers' questionnaire are two statements. The teachers could rate their agreement with these statements on a 7-point Likert scale. The first statement concerned the awareness the teacher had of their attention distribution during the lesson. The second statement concerned the teachers' satisfaction with their own attention distribution during the lesson.

The students also completed a questionnaire after each lesson. This questionnaire consisted of two statements, the students could rate their agreement with these statements on a 7-point Likert scale. The first statement was about whether the students received the attention they needed from their teacher. The second statement was about whether the students felt distracted by the research.

All of the questionnaires consisted of items that were developed by the researchers, combined with existing rating scales (RSME's and 7-point Likert scales) and can be found in Appendix 1.

Procedure

The data was gathered by tracking ten secondary school teachers during four of their lessons. Two of those lessons the teacher received feedback, because the FireFlies V2 system was implemented in their classroom (this was the experimental condition). The other two lesson the teacher was only tracked, without receiving feedback: The FireFlies were not present in the classroom (this was the control condition). It was decided to not place the FireFlies in the classroom at all, because baseline measure was desired for the control condition: It should be as much like a normal lesson as possible. The order in which the teachers experienced the control and experimental condition was counterbalanced.

During all four lessons, the teacher was wearing the tracking device and tracking data was gathered. At the end of each lesson, both the teacher and students received the questionnaires and there was a short interview with the teacher.

Data-analysis

Data preparation

The tracking data was prepared in such a way that the distribution of the teachers' presence in the front-end and back-end of the classroom was calculated. The amount of data in the front of the classroom was divided by the amount of data in the back of the classroom. The result's distance to 1 was calculated and this was taken as a measure of the teachers' distribution of their presence. The RSME's were measured and all the data from the questionnaire was put into SPSS. The students' questionnaire ratings were put into a separate SPSS file.

Data-analysis

All of the quantitative data of the teachers was analyzed using a double multivariate repeated-measures-ANOVA in SPSS, because all of the teachers experienced all of the conditions. Condition was the first within-subject factor with two levels (with/without FireFlies V2), and selected for the within-subjects model. The second within-subject factor was 'lesson', also with two levels (1/2), because there were two lessons for every condition. This second within-subject factor 'lesson' was not selected for the within-subjects model, because the hypotheses concern the effects of the condition and not of the lesson number. The dependent factors were

the teachers' scores on the two RSME's, the two Likert scales and the teachers' distribution of presence. The teachers' experience was selected as a covariate.

The quantitative data of the students was analyzed using a multivariate ANOVA in SPSS. The condition (with/without FireFlies V2) was selected as the independent variable and the students' scores on the two Likert scales were selected as the dependent variables. The number of students in the lesson was selected as a covariate.

Results

Teachers

An overview of the results from the double multivariate repeated-measures-ANOVA is presented in Table 2. The main effect of Condition was not significant ($F(5, 3) = 1.819$, $p = .330$). However, the effect size of condition was large ($eta^2 = .752$). Also the interaction of Condition x Experience was not significant ($F(5, 3) = 0.868$, $p = .586$) but also here the effect size was large ($eta^2 = .591$).

The univariate test results are not discussed because the main effects are not significant, so it should be concluded that none of the dependent variables were affected by either independent variable or interaction thereof: The RSME's considering the teacher's attention distribution and the teacher's reflection on attention distribution; the Likert scales considering the teacher's awareness of attention distribution and the teacher's satisfaction with their attention distribution; and the teacher's distribution of presence over the front and back of the classroom were all not affected by the implementation of the FireFlies V2 system.

The lack of a significant effects accompanied by large effect sizes suggests the sample of teachers was too small for significant effects to be found.

Table 2.

Results double multivariate repeated-measures-ANOVA

Dependent variable	Condition	Condition x Experience
RSME reflection on attention distribution	F(1, 3) = 0.220 eta² = .031	F(1, 3) = 0.252 eta² = .035
RSME attention distribution	F(1, 3) = 0.890 eta² = .113	F(1, 3) = 1.106 eta² = .136
Likert scale awareness of attention distribution	F(1, 3) = 0.177 eta² = .025	F(1, 3) = 0.163 eta² = .023
Likert scale satisfaction with attention distribution	F(1, 3) = 15.907** eta² = .694	F(1, 3) = 9.059* eta² = .564
Presence (front – back distribution)	F(1, 3) = 0.272 eta² = .037	F(1, 3) = 0.933 eta² = .118
Double multivariate	**F(5, 3) = 1.819** **eta² = .752**	**F(5, 3) = 0.868** **eta² = .591**

* p < .05; ** p < .01; *** p < .001

Students

Table 3 shows the effects of the condition (implementation/no implementation of the FireFlies V2 system in the classroom) on both dependent variables (the students' scores on two Likert scales), regarding the students: There is a significant main effect of condition (F(2, 811) = 18.989, p = .000). This effect is weak (eta² = .045).

The univariate tests show the effect of condition is on the students' responses to the Likert scale concerning their distraction by the research (F(1, 812) = 38.005, p = .000). However, this effect is weak (eta² = .045). Figure 2 shows this: There is a small difference between the levels of distraction in the experimental (M=2.70, SD=1.63) and control condition (M=2.04, SD=1.39).

Condition has no effect on the students' responses to the Likert scale concerning the attention the students received from the teacher (F(1, 812) = 1.363, p = .243). The number of students did not have significant effect on the students' responses to either Likert scale (F(2, 811) = 0.301, p = .740).

Table 3.

Results multivariate ANOVA

Dependent variable	Condition	Number of students
Likert scale attention received from teacher	F(1, 812) = 1.363 eta² = .002	F(1,3) = 0.272 eta² = .037
Likert scale distracted by research	F(1, 812) = 38.005*** eta² = .045	F(1,3) = 0.272 eta² = .037
Multivariate	**F(2, 811) = 18.989*** **	**F(2, 811) = 0.301**

* p < .05; ** p < .01; *** p < .001

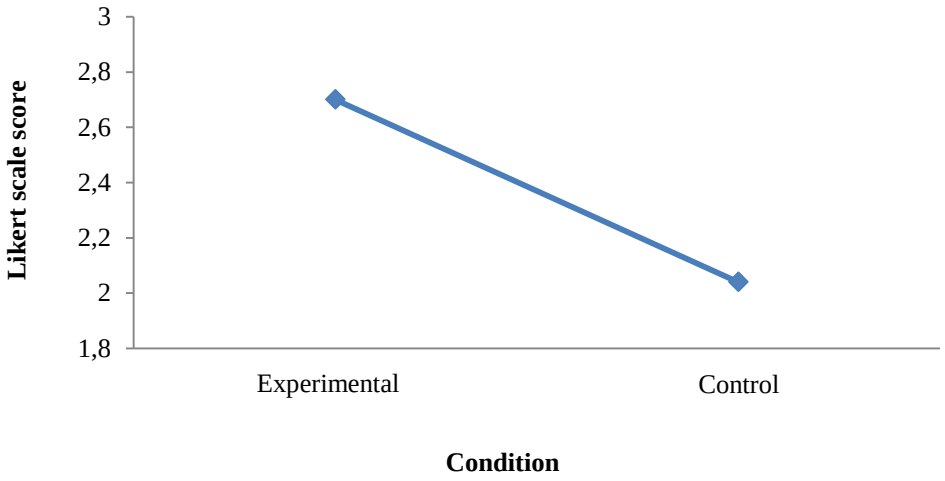

Figure 2. Visualization of the only significant effect of condition (on the students' responses to the statement inquiring about the level of distraction by the research they experienced) on a 7-point Likert scale.

Discussion

This research was conducted to study how the newly developed classroom technology FireFlies V2 influences both teachers and students when it is implemented in the classroom. The results show that none of the teachers' measures were significantly influenced by the FireFlies V2 system: The teachers did not feel more aware of their attention distribution when the FireFlies V2 system was implemented. They also did not distribute their presence more evenly over the front and back of the classroom. The teachers did not feel more satisfied when

the FireFlies V2 system was implemented. The teachers' self-reported mental effort was also the same in both conditions.

The first hypothesis concerns the teachers' awareness of their distribution of time and attention over the students, the effects this has on the teachers' actual movement through the classroom and their satisfaction with their own attention distribution. It was expected that the teachers would feel more aware in the lessons with FireFlies V2 than in the lessons without and that this would result in a more even distribution of the teacher's presence over the classroom in the experimental condition, which would also be expressed through self-reports: A higher satisfaction of the teachers with their attention distribution when the FireFlies V2 system was implemented. This hypothesis was based on the purpose of the system: FireFlies V2 was developed to give teachers real-time feedback, the goal was that as a result, the teachers would be more aware of their behavior and adjust their behavior accordingly if necessary. This purpose of the system was mainly based on the research by An et al. (2016), which suggested that teachers have to spend a lot of time on reflective tasks and that providing more information in the periphery of attention could assist the teacher with these tasks.

This hypothesis was not confirmed by the quantitative data. Teachers do not feel more aware and also do not spread their presence more evenly over the front and back of the classroom as a result of the implementation of the FireFlies V2. The teachers also do not feel more satisfied with their attention distribution. It is a logical consequence of the fact that the teachers do not behave differently when the FireFlies V2 system was used, that the teachers also are not more satisfied with their behavior.

One possible explanation for this lack of effect is that teachers do not need the FireFlies V2 system to assist them in their reflective tasks, even though the study by An et al. (2016) suggests this. Another possible explanation for the lack of significant effects is the study set-up. Both in the lessons with and without FireFlies V2, the teachers wore a sizeable tracker (see figure 1) and were aware of taking part in an experiment and being tracked. This simple fact could already have increased the teacher's awareness of their presence distribution over the classroom. As mentioned in the results, the sample of teachers could also have been too small to find a significant effect.

The other hypothesis for the teachers concerns the teachers' self-reported mental effort, which is a measure of the experienced cognitive load. It was expected that the self-reported mental effort would be lower in the condition with FireFlies V2 than in the condition without. This was not confirmed by the data, there was no significant difference between the

two conditions. This suggests that the FireFlies V2 cannot function as an external part of the teacher's cognition (Hollan, et al., 2000). However, these results also show that the FireFlies V2 system does not provide extra cognitive load in the teacher's experience, which is in line with the idea that FireFlies V2 enable interaction in the periphery of attention and that this does not require a lot of mental resources (Bakker, 2013). Also for these results it should be mentioned that there is a possibility that the sample of teachers was too small to find significant effects.

The results of the students' self-reports regarding the first hypothesis show that in both conditions, the students felt like they received the attention they needed from the teacher: Both averages of the answers the students provided for the statement "I felt like I received the attention I needed from the teacher during this lesson" correspond with 'agree' on the Likert scale. The implementation of the FireFlies V2 system did not make the students agree more with this statement. A possible explanation is the same as the explanation for the lack of difference in the teacher's awareness and spreading of presence throughout the classroom: The teachers do not need the assistance of the FireFlies V2 system, even though this is suggested by An et al. (2016). However, also in this case an alternate explanation is possible: The teacher's realization of being tracked might have created awareness of their behavior, also when the FireFlies were not implemented. This awareness might have influenced the teacher's behavior and consequently the students' experience of this behavior.

The second student hypothesis was that the students would feel more distracted in the experimental condition. The results show that the students felt slightly more distracted in the experimental condition (M=2,70) than in the control condition (M=2,04), which is understandable since the FireFlies were placed on their tables and changing color during the experimental condition. However, both averages correspond with an answer category somewhere between 'disagree' and 'completely disagree' on the Likert scale, so this is not a worrisome result: The students still did not agree with the statement "I felt distracted by the research during this lesson".

In addition to the proposed explanations for the results, some remarks about the methodology of this research should be noted. First of all, this was a field experiment, meaning the manipulation of using the FireFlies V2 system did not take place in a controlled setting, but in a real life secondary school classroom. As a result, more can be said about the actual consequences of placing this system in a real life classroom. However, this also means a lot of other factors influence the behavior and mental states that are measured, like the lesson content or the amount of student in the lesson. This, in combination with having a

relatively small sample of ten teachers, creates the need to be extra careful when interpreting the results: The effects, or lack thereof, cannot be solely contributed to the placement of FireFlies V2.

The qualitative data that was also gathered in this research, but not yet discussed, might bring more insights and explanations of the quantitative findings. Future research in this direction might consider testing technologies for classroom settings in a controlled environment, in addition to placing them in a real life setting. In this way, the effects of the system can be separated from other influences. Another way to increase the chance of finding an effect if it is there, is using a larger sample of teachers. A suggestion for improving the current FireFlies V2 system is making the system more subtle by for example using smaller lights that are embedded in the students' tables and adjusting the tracker so that it's less of an obtrusion. This can prevent students' distraction and avoid the teacher's constant awareness of being tracked.

In conclusion, design for peripheral interaction in general seems to be a promising research direction. The FireFlies V2 system, which aimed to enable interaction in the periphery of attention, did not cause the teachers to experience extra cognitive load. Furthermore, using experiments to test new technologies has proven to be an interesting method which hasn't been done before, but could be improved in the future. Similarly, the multidisciplinary approach that was used for this research is very insightful and shows great potential for future collaborations.

Appendix 1A – Questionnaire that the teachers completed after every lesson

Met aandacht-verdeling bedoelen we hier de verdeling van je tijd en aandacht over verschillende leerlingen, om ze te ondersteunen bij het leerproces.

1. Hoe inspannend vond je het deze les om je aandachts-verdeling **in de gaten te houden**?

   (geef aan door een kruisje te zetten op de verticale lijn)

2. Hoe inspannend vond je het deze les om je aandacht te verdelen?

Geef aan in hoeverre je het eens bent met de volgende stellingen:

1. Ik had in de gaten hoeveel tijd ik op verschillende locaties in de klas was (bij verschillende leerlingen) tijdens deze les

Helemaal mee oneens	Mee oneens	Neutraal	Mee eens	Helemaal mee eens

2. Ik ben tevreden over hoe ik deze les mijn aandacht over de leerlingen verdeeld heb

Helemaal mee oneens	Mee oneens	Neutraal	Mee eens	Helemaal mee eens

Appendix 1B – Questionnaire that the students completed after every lesson

Geef aan in hoeverre je het eens bent met de volgende stellingen door 1 bolletje in te kleuren

1. Ik heb deze les de hulp gekregen die ik nodig had van de leraar

Helemaal mee oneens	Mee oneens	Neutraal	Mee eens	Helemaal mee eens

2. Ik voelde me afgeleid door het onderzoek deze les

Helemaal mee oneens	Mee oneens	Neutraal	Mee eens	Helemaal mee eens

Dit heb ik er nog over te zeggen:

Appendix 2A – Recruitment e-mail

Beste meneer/mevrouw,

Wij zijn onderzoekers van de Technische Universiteit Eindhoven.

Op dit moment doen we onderzoek naar het ontwerp van technologische systemen die leraren in het voortgezet onderwijs kunnen helpen.

We zijn nu op zoek naar leraren in het voortgezet onderwijs die de nieuwe technologie willen uitproberen in hun les.

Het gaat om een zogenaamd ‘smart system’ dat op een vriendelijke manier informatie geeft over hoe de leraar zijn/haar tijd en aandacht aan verschillende leerlingen heeft gegeven tijdens de les. De leraar hoeft hier zelf niets voor te doen.

We zullen de technologie installeren in de klas, het enige wat de leraar vervolgens hoeft te doen is de technologie ervaren en deze ervaring met ons delen. Het feedback systeem zal voor 2 lesuren gebruikt worden. Tijdens 2 andere (vergelijkbare) lesuren, zullen we alleen metingen doen zonder dat het systeem gebruikt wordt.

Het systeem kan de leraar inzicht geven in zijn/haar manier van lesgeven. Ook zal de data gevisualiseerd worden in een kunstprint en deze zal de leraar ontvangen als cadeau.

We zijn op zoek naar leraren die voldoen aan de volgende vereisten:

- Normaal gezien zitten er 20 of meer leerlingen in de les;
- In de les zit een periode waarin de leraar rondloopt om individuele leerlingen te helpen, terwijl de leerlingen zelfstandig leren of oefeningen maken.

Bijgevoegd is een flyer waarin dezelfde informatie staat, gericht aan de leraren.

Graag horen we van u of er geïnteresseerde leraren zijn.

Vriendelijke groeten,

Sara Ordanovski

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