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Unpacking the black-box of students' visual attention in Mathematics and English classrooms: Empirical evidence using mini-video recording gadgets

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Abstract

With the technological improvements of innovative portable recording gadgets, augmented researchers' interest in exploring students' visual attention in their natural and normal occurring classrooms. The purpose of this study was to gauge students' visual attention in their Mathematics and English classrooms. This article reports on a study conducted in three schools in Santiago, Chile, where a sample of 113 randomly selected students wore a mini-video camera mounted on eyeglass in their Mathematics and English lessons. Using Google images, we automatically and objectively examined 723,600 frames from the recordings where the classroom teacher appeared in the students' visual field. The results show that students' visual attention varies depending on four factors: (a) gender of the student, (b) age of the students, whether students are low/high attainers and (d) whether students are in English or Mathematics lessons. Surprisingly, students significantly paid more visual attention in their Mathematics than in English lessons. High attainers were more visually engaged than their low attainers counterparts. Students appeared to be visually engaged differently at different stages in their education. Furthermore, girls were more visually engaged than boys. The results of this study can have enormous practical implications for teachers and teacher education, in order to be better visually engaged with students during teaching.

KEYWORDS
age, gender difference, GPA, Mathematics, student visual attention

1 | INTRODUCTION

Understanding patterns of nonverbal classroom interactions between students and teachers has been an area of interest (Breda et al., 2020; Farsani, 2016; Hernández et al., 2020). Nowadays, new and widely accessible technological gadgets enable researchers to explore the black box of students' visual attention more accurately. This article reports on a study conducted in three schools in Santiago, Chile, where a sample of 113 randomly selected students (42 girls and 71 boys) wore a mini video camera mounted on their eyeglasses in order to gauge students' visual attention in their Mathematics and English classrooms. In many countries that English is not the medium of instruction including Chile, students are expected to excel well in English. Having an adequate level of numeracy is associated with a reduced likelihood of economic disadvantage and unemployment. It is commonly perceived that with high English and Mathematics competencies, students are more successful in tertiary education and have better employment opportunities (OECD, 2013). Unlike the old and traditional studies in educational research where a researcher used to place a camera on a tripod at the back of the classroom (which is the

third person's perspective), in this study, we are using a first person's perspective (by placing mini-cameras mounted on students' eye glasses) in order to capture and report the classroom interaction from the students' own perspectives.

Visual attention is how one focuses attention on the specific target in spite of distractors in the environment (Wolfe & Horowitz, 2017). Visual attention is a multidimensional construct that includes sustained attention (vigilance), selective discrimination of relevant from nonessential information, and inhibition of responses to nonessential targets (Hoffman et al., 2018; Oakes & Amso, 2018). To date, the eye-movement methodology has successfully been applied to reveal the moment-to-moment activity of the mind and to provide valuable insight into readers' visual attention while learning from texts (Koning et al., 2010; Liao et al., 2020; Shvartsa & Abrahamson, 2019; van Meeuwen et al., 2014). A plethora of studies have established that attention is related to school achievement (Chan & Wong, 2019; Hwang et al., 2018; Muhonen et al., 2020). The results of longitudinal research have shown that the initial span of children's attention can significantly predict the long-term decline in academic achievement and job skills (Jarodzka et al., 2013). Attention skills allow children to successfully direct their attention in the early years of elementary school by equipping children with abilities such as focusing on teacher's teaching, completing tasks, and following classroom rules and attention to social and learning-related situations and relationships, such as cooperative and competitive learning situations (Habók et al., 2020).

Given this vital role of attention in providing the basis for learning, cognitive development, and behavioural regulation, it can be assumed that improving attention potentially can increase academic and cognitive abilities and reduce problematic behaviours in the early years of childhood (Kirk et al., 2019). Investigating the impact of attention training has had far-reaching consequences for primary school children and not only for clinical populations; among other things, attention training can enhance cognitive abilities, improve academic achievement, and reduce behavioural problems in a wide range of children with attention-deficit problems (Kirk et al., 2019). Such meaningful results can provide evidence-based tools for teachers to support learning (Kirk et al., 2017b). Studies have shown a link between visual attention and students' learning and performance and academic achievement (Pinto et al., 2018). However, to date, there is a lack of empirical research suggesting how students' visual attention is influenced by their gender, age, subject (Mathematics vs. English), and their academic achievements (high/low attainers). Therefore, this study explores the following research questions:

- How boys and girls are visually engaged in Mathematics and English classrooms?
- Do students' visual attention differ at different stages in their education?
- Do high/low attainers differ in paying visual attention in Mathematics and English classrooms?
- How students are visually engaged in their Mathematics versus English classrooms?

2 | LITERATURE REVIEW

In this section, we unpack previous studies that centred on the notion of visual attention. In each of the subsequent four subsections, we draw upon how the role of (a) gender, (b) age, (c) low/high attainers and (d) different subject disciplines (e.g., English vs. Mathematics) has an effect on students' visual attention.

2.1 | Gender and visual attention

To the best of our knowledge, very few research reports exist examining how students' gender has an effect on their visual attention in their classrooms. Due to the scarcity of research in educational research, we draw upon other disciplines such as psychology, neuroscience, and embodied cognition. Gender differences in cognitive abilities have long been studied, leading to a strong literature on this subject. The results of Naglieri and Rojahn (2001), which examined Planning, Attention, Simultaneous, Successive (PASS) cognitive-processing theory, built on the neuropsychological work of Luria (1973) on 1100 girls and 1100 boys, suggested that girls perform better than boys on the scale of planning and attention (Naglieri & Rojahn, 2001). Learning requires attention, and thus visual attention is an integrated part of cognitive processing of information (Koning et al., 2010; Van Der Veen & Van Oers, 2017). Pinto et al. (2018) highlighted significant gender differences for the conception of learning as a co-constructive and cultural process, which showed a higher prediction on academic outcomes for females rather than males. This represents a useful step in the perspective of promoting awareness of the role and impact of conceptions of on academic success also across gender differences (Pinto et al., 2018).

Various theories have explained the role of gender differences in learning processes. According to selectivity theory, different parts of the male and female hemispheres are activated to perform different information processing strategies (Meyers-Levy & Loken, 2015). Cárdenas et al. (2013) identified gender differences in visual attention to infants' faces. For example, female's visual attention to infants was stronger and more stable than that of males (Cárdenas et al., 2013). The effect of gender difference on visual attention has also been obtained in Hwang and Lee (2018) research. The aim of their study was to investigate the effect of gender on visual attention in online shopping information using an eye-tracker, which showed that female participants performed better in terms of visual attention (Hwang & Lee, 2018). Females are known to possess better recognition memory because of their greater visual scanning behaviour (Heisz et al., 2013). Finally, in their study of first-grade students, Farsani and Mendes (in press) showed that six-year-old boys and girls varied in their visual attention to their teachers. This variation was due to their proxemics relation to their teachers. These young girls were more visually engaged to their teachers at a closer proxemics distance (within 120 cm), whereas boys paid more visual attention to their teachers at a further distance (between 120 to 370 cm).

To date, very few research studies reported how students' gender has an effect on their visual attention in their classrooms. Studies outside of the classroom illustrate that female's visual attention is stronger and more stable than of males (Cárdenas et al., 2013; Hwang & Lee, 2018) and that males have a greater visual scanning behaviour (Heisz et al., 2013). Research studies within the classroom context illustrate that difference between male and female students' visual attention could depend on their proxemics relation with their teacher where boys are more visually engaged at a greater distance but girls are better engaged at a closer distance (Farsani & Mendes, in press).

2.2 | Age differences and visual attention

The findings of previous studies on age and its positive effects on visual attention are scarce and mixed (Araya & Hernández, 2016). For example, the findings of Isaacowitz et al.'s research (2006), which studied preferences in visual attention, eye tracking, and dot-probe, as students of various age groups younger and older adults viewed synthetic emotional faces. Their eye-tracking results most consistently revealed a positivity effect in older adults' attention, so that older adults showed preferential looking towards happy faces and away from sad faces. Dot-probe results were less robust, but in the same direction (Isaacowitz et al., 2006). Older adults are often slower and less accurate than are younger adults in performing visual-search tasks, suggesting an age-related decline in attentional functioning. Age-related decline in attention, however, is not entirely pervasive. Visual search that is based on the observer's expectations (i.e., top-down attention) is relatively preserved as a function of adult age. Neuroimaging research suggests that age-related decline occurs in the structure and function of brain regions mediating the visual sensory input, whereas activation of regions in the frontal and parietal lobes is often greater for older adults than for younger adults (Madden et al., 2007). This increased activation may represent an age-related increase in the role of top-down attention during visual tasks (Madden, 2007). For young primary students, “timing” is a crucial factor that can influence students' visual attention. In a study that was conducted with 36 students (21 boys and 15 girls), reported that 10.5 year olds students tended to have more moments looking at other students during the sessions in the morning than in afternoon (Araya et al., 2015). They reported that during the morning sessions, the tendencies for both male and female students to look at the teacher (0.453 for males and 0.355 for females) were much higher than for the afternoon sessions (0.211 for males and 0.148 for females). Therefore, the notion of ‘time of the day’ appears to be factors that can have effects on younger students' visual attention.

Previous research studies on eye-tracking and brain scanning suggest that adults tend to be more perceptive to positive faces and slower and less accurate in performing visual tasks in comparison to the younger ones. Other researchers have focused on the notion of timing in educational context, and concluded that students' visual attention reaches its peak at about the 40 min in the lesson for primary school students (Araya & Hernández, 2016; Farsani et al., 2020).

2.3 | Low and high attainers and visual attention

Visual attention also plays an important role in students' academic performance. In this article, we refer to low and high attainers as students with lower and higher Grade Point Average (GPA), respectively. Visual attention has been highlighted as a key facilitator in the development of complex cognitive skills, and a particularly salient predictor of academic outcomes (McClelland et al., 2013). In particular, visual attention skills have been emphasized as integral to learning, with visual search and visual sustained attention being associated with core academic skills such as literacy and numeracy. Visual attention plays an important role in directing attention within the classroom (Chan & Wong, 2019; Kirk et al., 2017a). In Chile, Farsani et al. (2020) reported on a study that comprised of only 33 girls with different learning abilities in their Mathematics lessons. They concluded that girls with a higher GPA level were significantly more visually engaged during teachers' instructional information, particularly during the first 40 min of the lesson, in comparison to their lower GPA counterparts. In another study that was conducted with only one primary teacher, Araya et al. (2015) showed that high GPA students had a higher tendency to look at the teacher (0.417) than their lower GPA counterparts (0.324). Furthermore, the teacher's tendency to look at high GPA students (0.580) was much higher than his tendency to look at low GPA students (0.420).

Visual attention appears to play an important role in students' academic performance. Interestingly enough, high GPA primary school students are more likely to be more visually engaged during teaching than their low GPA counterparts (Araya et al., 2015; Araya & Farsani, 2020; Farsani et al., 2020).

2.4 | Different subject disciplines and visual attention

To date, very little research reports exist on how students' visual attention varies in different subject disciplines, in particular in Mathematics and English classrooms. Across the elementary and secondary grade levels, students are expected to learn Mathematics across a variety of domains. Haataja et al. (2019) reported on a study that was conducted to investigate the relationship between a teacher's scaffolding intentions and his gaze behaviour, during a Mathematics lesson using mobile gaze tracking devices. They reported that the teacher's scaffolding intentions affected his gaze targets significantly and that mobile gaze tracking can provide novel insight to situational processes of teacher–student interactions (Haataja et al., 2019). Students were more visually engaged in their Mathematics lesson where the teacher's instructional talk was accompanied by teacher's gestures (Edwards et al., 2014; Rasmussen et al., 2004). This finding is in line with a study that was conducted with fourth graders in a public school in Chile, where students' gaze on the teacher lasted 44.9% longer when the teacher gestured during his instructional information than when he did not, with an effect size (Cohen's *d*) of 0.69 (Araya et al., 2016). In another study, students appeared to be more visually active by looking at other students and also the teacher in their Mathematics, Language and Technology

lessons (44.0%, 48.9%, 50.5%, respectively) than in the other subjects, such as Computer Labs (15.8%) and Science (33.3%) (Araya et al., 2015). Both males and females students had the tendency to look at the teacher a lot more in their Mathematics lessons (0.463 for male students and 0.621 for females students) than in other lessons. Furthermore, high GPA students had a much higher tendency to look at the teacher (tendency is 0.593) in Mathematics than in other classes (e.g., 0.246 for art class), which was statistically significant with a *p*-value = 0.004. There is particular emphasis on learning English and Mathematics at an early age in different parts of the world (OECD, 2013).

Previous studies reported that students are likely to be more visually engaged in their Mathematics than in English lessons (Araya et al., 2015; Farsani & Mendes, in press). There are some interesting factors that seem to have an effect on students' visual attention to their teachers (Wolff et al., 2017). Researchers have focused on differences such as: gender (e.g., Heisz et al., 2013), age (e.g., Isaacowitz et al., 2006), GPA (e.g., Farsani et al., 2020), and different subject disciplines (e.g., Araya et al., 2016). However, those previous studies were conducted on a small scale working with a teacher in one classroom. The findings of this study will significantly contribute to the ongoing literature in the field of students' visual attention due to its large scale and unique methodological approach that emphasizes on the first person's perspective (Wang et al., 2020).

3 | METHODOLOGY

Over the last 50 years, video recordings have become central for recording and analysing classroom interactions. Overtime, with the improvements of audio-visual devices and recording technologies, these recording gadgets have not only enhanced their quality and recording duration, but also improved in sizes. Nowadays, eye-tracking devices are widely used in educational research, measuring students' visual attention during lessons (Araya et al., 2016; Sharma et al., 2014; Prieto et al., 2017), and in other social contexts such examining readers' actual visual interaction with a newspaper (Holsanova et al., 2006). However, there are downsides to the employment of eye-tracking devices, due to their high price in the market for educational research. In order to conduct a medium–large size sample, eye tracking devices can be costly. For the current research, 113 randomly selected students (42 girls and 71 boys) wore a mini video camera mounted on eyeglasses in their Mathematics and English lesson. It is worth noting that these mini video cameras mounted on students' eyeglasses are not the same as eye-tracking (Boeriis & Holsanova, 2012). These eyeglasses are cheap, widely accessible and ideal for research implementations particularly for medium–large sample sizes (see Figure 1).

The idea of using gaze as a medium for analysing the learning processes is of interest to many researchers (Araya & Farsani, 2020; Araya & Hernández, 2016). This is due to the fact that a student's visual attention 'emerges directly from' the student him/herself, which is the first person's perspective. Traditionally in many educational studies, researchers put a camera on a tripod to capture the classroom interactions between the teacher–students and student–students, which is the third person's perspective. Therefore, in this paper, we will pay particular attention to the importance of the first person's viewpoint, something that traditionally has not been paid a great deal of attention to. By mounting cameras on students' eyeglasses, we were able to compute and obtain a better perspective of the class, as observed by the student, in order to open the black box of classroom interactions (Farsani & Mendes, in press).

FIGURE 1 Mini camera mounted on a student's eyeglasses [Colour figure can be viewed at wileyonlinelibrary.com]

3.1 | Study sample

Our sample consisted of 113 students, including 16 first grade students (6.5 years of age), 55 fourth graders (age 10.5 years of age), 11 sixth graders (12.5 years of age), and 31 eighth graders (14 years of age) from three different schools in Santiago, Chile. We obtained extra information from the subject teacher about each student. Therefore, a profile was created for each student based on their (a) gender, (b) age, (c) recorded subject, and (d) their academic achievements, or GPA. Fifty-three out of the 113 students were perceived to be high attainers (high GPA) and 60 were identified with low GPA. In every subject, 'average' of students' collective marks was obtained. Students who obtained a higher mark than the 'average' were then put in high GPA and consequently, students who obtained a lower mark than the collective average mark, were considered to be in low GPA group.

3.2 | Procedure

These students had previously used the cameras on a trial basis to ensure that the experiment did not appear to them as a surprise and that the experiment took place in as natural setting possible. Capturing the live interactions through the mini-camera mounted on students' eyeglasses allowed capturing everyday interactions and meaning-making practices from the students' own perspective. The original eyeglass lenses were removed so as to minimize the weight and

to facilitate the original view. Each lesson lasted 90 min long and each student had to wear the eyeglasses for the full duration of the lesson.

At the end of each day, the recordings were manually downloaded onto a computer. The video cameras had a recording quality of 30 frames per second (30 fps); for each video, a frame was sampled every second and processed in order to detect the presence of the teachers' faces. From each student, we obtained 5400 (60 frames per minute × 90) frames during the 90 min lesson, where each frame represented 1 s of the classroom interaction. In total, 723,600 ([113 + 17 + 4 = 134] × 5400) frames were obtained from the 113 students as 17 students wore the cameras in two lessons, and two students used these cameras in three lessons (see Table 1). In total, we had students participating in 62 Mathematics lessons and in 72 English lessons. As mentioned earlier, we selected one frame (from the 30 fps) to represent 1 s. In other words, each frame represents a photo, 'imprint of reality' (Jewitt & Oyama, 2001, p.151) which enables us to attend at particular moments in time from the students' own perspective in their classroom interaction.

Every sampled frame (each frame representing 1 s) that was captured from students' eyeglasses was saved on Google Photos. We also inserted photos of the classroom teacher (full face and side profiles), and by using facial recognition on Google Image option, we automatically and objectively identified all the frames where an image of a teacher appeared in each frame that was captured by students. The first author later checked each of these frames, ensuring that the faces were correctly identified. Every frame was given a unique ID number. This ID number revealed information about the observer (e.g., being a boy or a girl, and at what minute/second was captured). This unique ID number, which revealed information about the observer enabled pursuing different attributes that effect the observer's visual attention in the classrooms. It is worth noting that, the data that emerge in this paper are primarily from the first person's perspective (students themselves), not a descriptive account of a third person's perspective (data that are captured from a camera on a tripod at the back of the classroom) that research in visual classroom discourse traditionally has taken account.

In our study, consent forms were obtained from all students, parents/carers of the students, the classroom teachers and the institutional authorities (e.g., school director). Students' and teachers' participations in our study were on a voluntarily basis, and there were no financial incentives in order to obtain a closer sense of their naturally occurring interactions in their classrooms.

4 | RESULTS

In the first set of quantitative analyses, we explore the relationships between students' visual attention to teachers (SVAT) and students' characteristics, including gender, subject discipline, year of study, and GPA. A series of chi-square (χ^2) test of associations were conducted given that all the variables are measured at categorical levels using zeros and ones for SVAT (attention or no attention), gender (male or female), and GPA (low or high). Subject enrolment was coded as 1 for Mathematics and 0 for English while the year of study was coded as 1, 4, 6, and 8 that are corresponding to students' year of study, respectively. The results of the pairwise chi-square tests are combined and summarized in Table 2.

The presented results in Table 2 show that all the students' characteristics are statistically associated with the students' visual attention to the teachers. The chi-square value ($\chi^2_{(1)}$ = 359.80) for gender is significant ($p < 0.001$), which shows that students' visual attention is dependent on whether students are males or females. A similar interpretation of results holds true for subject enrolment and the GPA. The chi-square value ($\chi^2_{(3)}$ = 682.84) for the school year is as well significant ($p < 0.001$), which shows that students' visual attention to teachers is dependent on the year of study. The subscripts (*r*, *s*, and *p*) indicate pairwise comparisons of subsets of students in school years where differences are more pronounced. For instance, the visual attention of students in Year 1 and Year 4 (with subscript *r* and *s*) are statistically different while the visual attention of students in Year 1 and Year 6 (with the same subscript *r*) is not statistically different.

After we have found that students' visual attention to teachers is significantly dependent on some students' characteristics, we took a step further to investigate the prediction of students' visual attention to the teachers based on these characteristics. On this note, we performed a logistic regression analysis with the students' visual attention being predicted by gender, subject enrolment, year of study, and GPA. The results of this statistical analysis are presented in Table 3.

The presented results in Table 3 show the regression coefficients (B's) and other associated statistics for the prediction of students' visual attention to teachers from students' characteristics. All the students' characteristics predict the students' visual attention to teachers significantly though at varying strength of prediction. Gender has a non-standardized regression coefficient of $B = -0.233$ ($p < 0.001$), standard error of 0.017, and a Wald statistic of 179.295. Since gender is coded with 0 for females and 1 for males, an interpretation of the

TABLE 1 The distribution of the sample across the subjects and study years

	Male			Female			
	English	Mathematics	Total	English	Mathematics	Total	Total
Year 1	3	8	11	2	4	6	17
Year 4	14	14	28	15	23	38	66
Year 6	0	4	4	0	7	7	11
Year 8	28	12	40	0	0	0[1]	40
Total	45	38	83	17	34	51	134

[1]Due to the religious and cultural sensitivity, we did not have permission to include female students in our study in Year 8.

TABLE 2 Selected results of the chi-square test of an independent association between SVAT and students' characteristics

	Student visual attention to teachers						
	Yes		No				
	N	%	*N*	%	χ^2-value	Degree of freedom	*p*-value
Gender							
Female	7419	2.7	267,981	97.3			
Male	9008	2.0	439,192	98.0	359.80	1	<0.001
Subject							
Mathematics	11,064	2.8	377,736	97.2			
English	5363	1.6	329,437	98.4	1254.43	1	<0.001
School year							
Year 1_r	1379	1.5	90,421	98.5			
Year 4_s	9615	2.7	346,785	97.3			
Year 6_r	981	1.7	58,419	98.3	682.84	3	<0.001
Year 8_p	4452	2.1	211,548	97.9			
GPA							
High	9083	2.5	352,717	97.5			
Not high	7344	2.0	354,456	98.0	188.37	1	<0.001

TABLE 3 Selected logistic model results in predicting students' visual attention from students' characteristics

Variable	*B*	*SE*	Wald	Degree of freedom	*p*-value
Gender	−0.233	0.017	179.295	1	<0.001
School year	0.040	0.004	106.723	1	<0.001
Subject	0.585	0.017	1126.798	1	<0.001
GPA	0.209	0.016	171.109	1	<0.001
Constant	−4.875	0.040	15,068.296	1	<0.001

significant negative regression coefficient is that students' visual attention to teachers of females is better predicted by the model. Even though the regression coefficient of the school year (B = 0.04) appears to be small, it is significant (p < 0.001) with a standard error of 0.004 and Wald statistic of 106.723. This result confirms that the school year of the students is a relevant factor in predicting whether or not students pay visual attention to teachers.

The presented results in Table 3 also show that students' subject enrolment plays a significant role in predicting their visual attention to the teachers. The regression coefficient is positive (B = 0.585, p < 0.001), standard error of 0.017, and Wald statistic of 1126.798. Since the subject is coded with 0 for English and 1 for Mathematics, an interpretation of the positive regression coefficient is that students' visual attention to teachers in Mathematics classes is better predicted by the model. More so, it is also shown in Table 3 that students' GPA is a significant predictor of their visual attention to teachers with a regression coefficient of B = 0.209 (p < 0.001), standard error of 0.016, and Wald statistic of 171.109. Given that students' GPA is coded with 0 for low GPA and 1 for high GPA, an interpretation of the positive regression coefficient is that visual attention to teachers of students with high GPA is better predicted by the model. Perhaps, this result is not surprising as students with a high GPA are usually assumed to be more attentive in classroom instruction. Finally, the constant statistics that are presented in Table 3 represent the statistics of a baseline model in which no predictor variable is included.

5 | DISCUSSION AND CONCLUSIONS

This study set out with the aim of adding to the existing literature about the ways in which students of different: gender, age group and GPA levels are visually engaged in their Mathematics and English classrooms to their teachers. In this paper, we placed particular attention on the 'first person's perspective', where 113 randomly selected students wore a mini video camera mounted on their eye-glasses in order to capture and report the classroom interaction from the students' own perspectives. To date, very few studies have explored factors that can influence students' visual attention to teachers in their normally and naturally occurring settings (Araya et al., 2016; Araya & Hernández, 2016; Farsani & Mendes, in press). Furthermore, previous studies reported on either smaller sample of students, 33 (Farsani

et al., 2020) and 34 (Araya & Hernández, 2016); or smaller number of frames, whereby, for example, only 848 frames (Araya et al., 2016) were taken into account that emerged from student's perspectives. In this study, we analysed 723,600 frames that emerged from student's own perspectives, which is much larger in scale in comparison to the previous studies.

Students' visual attention to teachers is significantly dependent on some of students' characteristics, such as their gender. In this study, boys and girls were differently visually engaged to their teachers during Mathematics and English classrooms. This gender difference was statistically significant ($p < 0.001$), whereby girls paid 2.7% visual attention to the teachers, and boys were visually engaged only by 2%. Our research findings are also in line with previous research findings on gender and visual attention. Females out performed males in terms of visual attention (Hwang & Lee, 2018). This could be due to the fact that females possess better recognition memory because of their greater visual scanning behaviour (Heisz et al., 2013).

Students appeared to be visually engaged to their teachers differently at different stages in their education. Within our sample, highest students' visual attention to teachers found for Year 4 students (2.7%) and lowest identified for Year 1 students (1.5%). This could suggest that after students gain more experience in school and become more aware of the importance of paying attention to teachers, they tend to follow teachers' action more closely than younger students. Although further research is needed to confirm this observation, however, our findings were in line with Isaacowitz et al.'s study Isaacowitz et al. (2006) about the association between age and visual attention.

Interestingly, the data reported in Table 2 show that students' visual attention to teachers was lower in Year 6 and 8 (i.e., 1.7% and 2.1%) compared to Year 4. We speculate that Year 6 students (age 12.5) were in the age that puberty happens for many of them,[1] and that might negatively impact their attention to the teaching in the classroom, and consequently to their visual attention to teachers. Furthermore, in Chile, students in Year 4 have an important national examination that they do not sit in this examination in any other year. This could partially explain the reason as to why Year 4 students were more visually engaged to their teachers in their classrooms. Regarding Year 8 results, as our sample only includes male students at this level, 2.1% visual attention to teachers in the absence of female students was not surprising because as indicated earlier previous literature and our findings show that male students have lower visual attention compared to their female counterpart. Having 2.1% visual attention to teachers at Year 8, 0.1% higher visual attention rate than the total sample for male students again suggest that older students seem to have a higher attention to teachers than younger students.

Students' cognitive abilities played a major role in sustaining students' visual attention in classrooms. As previous studies (Araya & Hernández, 2016) suggested, students with high GPA were more visually engaged during teachers' teaching in comparison to their low GPA counterparts. Furthermore, low GPA students' gaze to the teacher decreases much more than high GPA students after the 40th minute during the lesson (Araya & Hernández, 2016). As illustrated in Table 2, students' GPA is a significant predictor of their visual attention to their teachers with a regression coefficient of $B = 0.209$ ($p < 0.001$). Students with higher GPA were 2.5% visually engaged in the classrooms, whereas this percentage was as low as 2% for their lower GPA counterparts. Our findings are in line with previous research, and the findings are not surprising as students with a high GPA are usually assumed to be more attentive in classroom instruction.

Students appeared to exhibit different patterns of visual engagement in their Mathematics and English classrooms. In Mathematics classrooms, students were 2.8% visually engaged, whereas this percentage was as low as 1.6% in the English classrooms. This difference was statistically significant with the p-value less than 0.001. This difference is indeed not surprising considering the nature of Mathematics. We speculate that students in Mathematics classrooms looked for other resources or means of meaning making (e.g., being more visually engaged on their lesson in order to compensate for their lack of understanding (Prediger et al., 2019)), such as gestures teachers produced during teaching (Radford, 2009; Rasmussen et al., 2004). Our research findings, albeit implemented in a greater scope, are in line with previous work (Araya et al., 2016) where only a sample of 34 students appeared to be more visually engaged in mathematics than in English lessons.

The above four factors appeared to have an effect on students' visual attention to their teachers during their Mathematics and English lessons. However, it is important to observe that girls and boys paid visual attention to their teachers only 2.7% and 2% of the time, respectively. This is to say that girls and boys were not visually engaged 97.3% and 98% of their time during the lesson, respectively. This is shocking and simultaneously disappointing. Furthermore, in a subject like Mathematics where we observed that students were most visually engaged during the class (2.8%), consequently signifies that students did not pay visual attention to their teacher 97.2% during the lesson.

We suggest sharing the findings of this study with teachers. They need to be mindful of students' visual attention span, particularly for low attainer students, and students at certain age and in a subject like mathematics. Given that students are visually engaged maximum 2.8% (Table 2) of the time during their lessons, this percentage is even lower for first graders primary school students and particularly those students with lower GPA. Considering higher GPA students that were more visually engaged in a subject like mathematics, still more than 97.2% of the times during the lessons, students were not visually engaged to teachers. We believe the first step to unpack the black-box of student visual attention is recognizing the reality of students' visual attention from the perspective of students themselves. Due to the improvements of technological gadgets, we are now enable to obtain the first person's perspective, and not the third person's perspective (e.g., teacher or researchers). Finally, teachers' nonverbal movements during conveying his/her instructional information could largely influence students' visual attention. Regardless of a teacher's experience, it is always worth questioning the forms, styles, and the quality of the messages that are conveyed verbally and nonverbally in professional teaching practice. Optimisation of these very subtle and silent nonverbal messages can have a direct positive impact by not only visually engaging students, but also on the teaching and learning

process. Further research is required to examine the ways in which teachers' nonverbal pedagogical style influences students' visual attention to teachers.

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ENDNOTE

[1] The average age for girls to begin puberty is 11, while for boys the average age is 12 (please see https://www.nhs.uk/live-well/sexual-health/stages-of-puberty-what-happens-to-boys-and-girls/).

DATA AVAILABILITY STATEMENT

Due to the nature of our data and the ethical guideline that this project follows, we, unfortunately, cannot share the data set.

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REFERENCES

Araya, R., Behncke, R., Linker, A., & van der Molen, J. (2015). Mining social behavior in the classroom. In M. Núñez, N. Nguyen, D. Camacho, & B. Trawiński (Eds.), *Computational collective intelligence. Lecture notes in computer science* (Vol. 9330). Cham: Springer. https://doi.org/10.1007/978-3-319-24306-1_44.

Araya, R., & Farsani, D. (2020). The effect of teacher unconscious behaviors on the collective unconscious behavior of the classroom. In M. Hernes, K. Wojtkiewicz, & E. Szczerbicki (Eds.), *Advances in computational collective intelligence. ICCCI 2020. Communications in computer and information science* (Vol. 1287, pp. 529–549). Cham: Springer. https://doi.org/10.1007/978-3-030-63119-2_43.

Araya, R., Farsani, D., & Hernández, J. (2016). How to attract students' visual attention. *Eleventh European Conference on Technology Enhanced Learning* (pp. 30–41). Springer International. https://doi.org/10.1007/978-3-319-45153-4_3.

Araya, R., & Hernández, J. (2016). Collective unconscious interaction patterns in classrooms. In N. Nguyen, L. Iliadis, Y. Manolopoulos, & B. Trawiński (Eds.), *Computational collective intelligence*. ICCCI 2016. Lecture Notes in Computer Science, 9876. Cham: Springer. https://doi.org/10.1007/978-3-319-45246-3_32.

Breda, A., Farsani, D., & Miarka, R. (2020). Political, technical and pedagogical effects of COVID-19 in mathematics education: An overview of Brazil, Chile and Spain. *INTERMATHS: Revista de Matemática Aplicada e Interdisciplinar*, *1*(1), 3–19. https://doi.org/10.22481/intermaths.v1i1.7400.

Boeriis, M., & Holsanova, J. (2012). Tracking visual segmentation: connecting semiotic and cognitive perspectives. *Visual communication*, *11*(3), 259–281.

Cárdenas, R. A., Harris, L. J., & Becker, M. W. (2013). Sex differences in visual attention toward infant faces. *Evolution and Human Behavior*, *34*(4), 280–287. https://doi.org/10.1016/j.evolhumbehav.2013.04.001.

Chan, W. L., & Wong, T. T. Y. (2019). Visuospatial pathways to mathematical achievement. *Learning and Instruction*, *62*, 11–19. https://doi.org/10.1016/j.learninstruc.2019.03.001.

Edwards, L. D., Moore-Russo, D., & Ferrara, F. (Eds.). (2014). *Emerging perspectives on gesture and embodiment in mathematics*. Charlotte: Information Age.

Farsani, D. (2016). Complementary functions of learning mathematics in complementary schools. In P. C. Clarkson & A. Halai (Eds.), *Teaching & learning mathematics in multilingual classrooms: Issues for policy, practice and teacher education* (pp. 227–247). Rotterdam: Sense Publishers.

Farsani, D., Breda, A., & Sala, G. (2020). ¿Cómo los gestos de los maestros afectan a la atención visual de las estudiantes durante el discurso matemático? *REDIMAT – Journal of Research in Mathematics Education*, *9*(3), 220–242.

Farsani, D., & Mendes, J. (in press). Proxêmica e comunicação não verbal na interação em sala de aula. *Psicologia Escolar e Educacional*.

Haataja, E., Garcia Moreno-Esteva, E., Salonen, V., Laine, A., Toivanen, M., & Hannula, M. S. (2019). Teacher's visual attention when scaffolding collaborative mathematical problem solving. *Teaching and Teacher Education*, *86*, 102877. https://doi.org/10.1016/j.tate.2019.102877.

Habók, A., Magyar, A., Németh, M. B., & Csapó, B. (2020). Motivation and self-related beliefs as predictors of academic achievement in reading and mathematics: Structural equation models of longitudinal data. *International Journal of Educational Research*, *103*, 101634. https://doi.org/10.1016/j.ijer.2020.101634.

Heisz, J. J., Pottruff, M. M., & Shore, D. I. (2013). Females scan more than males: A potential mechanism for sex differences in recognition memory. *Psychological Science*, *24*(7), 1157–1163. https://doi.org/10.1177/0956797612468281.

Hernández, J., Farsani, D., & Araya, R. (2020). An application of machine learning and image processing to automatically detect Teachers' gestures. In M. Hernes, K. Wojtkiewicz, & E. Szczerbicki (Eds.), *Advances in computational collective intelligence. ICCCI 2020. Communications in Computer and Information Science* (Vol. 1287, pp. 516–528). Cham: Springer. https://doi.org/10.1007/978-3-030-63119-2_42.

Hoffman, M., Tiddens, E., & Quittner, A. L. (2018). Comparisons of visual attention in school-age children with cochlear implants versus hearing peers and normative data. *Hearing Research*, *359*, 91–100. https://doi.org/10.1016/j.heares.2018.01.002.

Holsanova, J., Rahm, H., & Holmqvist, K. (2006). Entry points and reading paths on newspaper spreads: comparing a semiotic analysis with eye-tracking measurements. *Visual Communication*, *5*(1), 65–93.

Hwang, W. Y., Li, Y. H., & Shadiev, R. (2018). Exploring effects of discussion on visual attention, learning performance, and perceptions of students learning with STR-support. *Computers and Education*, *116*, 225–236. https://doi.org/10.1016/j.compedu.2017.09.015.

Hwang, Y. M., & Lee, K. C. (2018). Using an eye-tracking approach to explore gender differences in visual attention and shopping attitudes in an online shopping environment. *International Journal of Human-Computer Interaction*, *34*(1), 15–24. https://doi.org/10.1080/10447318.2017.1314611.

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Is there an age-related positivity effect in visual attention? A comparison of two methodologies. *Emotion*, *6*(3), 511–516. https://doi.org/10.1037/1528-3542.6.3.511.

Jarodzka, H., Van Gog, T., Dorr, M., Scheiter, K., & Gerjets, P. (2013). Learning to see: Guiding students' attention via a model's eye movements fosters learning. *Learning and Instruction*, *25*, 62–70. https://doi.org/10.1016/j.learninstruc.2012.11.004.

Jewitt, C., & Oyama, R. (2001). Vidual meaning: a social semiotic approach. In T. van Leeuwen, & C. Jewitt, (Eds.), *Handbook of visual analysis*, (pp. 134–156). New Delhi: Sage publications London. Thousands Oaks.

Kirk, H., Gray, K., Ellis, K., Taffe, J., & Cornish, K. (2017b). Impact of attention training on academic achievement, executive functioning, and behavior: A randomized controlled trial. *American Journal on Intellectual and Developmental Disabilities*, *122*(2), 97–117. https://doi.org/10.1352/1944-7558-122.2.97.

Kirk, H. E., Gray, K., Riby, D. M., Taffe, J., & Cornish, K. M. (2017a). Visual attention and academic performance in children with developmental disabilities and behavioural attention deficits. *Developmental Science*, *20*(6), e12468. https://doi.org/10.1111/desc.12468.

Kirk, H. E., Spencer-Smith, M., Wiley, J. F., & Cornish, K. M. (2019). Gamified attention training in the primary school classroom: A cluster-randomized controlled trial. *Journal of Attention Disorders*. https://doi.org/10.1177/1087054719887435.

Koning, B. B. D., Tabbers, H. K., & Rikers, R. M. J. P. (2010). Attention guidance in learning from a complex animation: Seeing is understanding? *Learning and Instruction*, *20*(2), 111–122. https://doi.org/10.1016/j.learninstruc.2009.02.01.

Liao, C.-N., Chang, K.-E., Huang, Y.-C., & Sung, Y.-T. (2020). Electronic storybook design, kindergartners' visual attention, and print awareness: An eye-tracking investigation. *Computers & Education*, *144*, 103703. https://doi.org/10.1016/j.compedu.2019.103703.

Luria, A. R. (1973). *The working brain: An introduction to neuropsychology*. New York: Basic Books.

Madden, D. J. (2007). Aging and visual attention. *Current Directions in Psychological Science*, *16*(2), 70–74. https://doi.org/10.1111/j.1467-8721.2007.00478.x.

Madden, D. J., Spaniol, J., Whiting, W. L., Bucur, B., Provenzale, J. M., Cabeza, R., White, L. E., & Huettel, S. A. (2007). Adult age differences in the functional neuroanatomy of visual attention: A combined fMRI and DTI study. *Neurobiology of Aging*, *28*, 459–476. https://doi.org/10.1016/j.neurobiolaging.2006.01.005.

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly*, *28*(2), 314–324. https://doi.org/10.1016/j.ecresq.2012.07.008.

van Meeuwen, L. W., Jarodzka, H., Brand-Gruwel, S., Kirschner, P. A., & van Merriënboer, J. J. G. (2014). Identification of effective visual problem solving strategies in a complex visual domain. *Learning and Instruction*, *32*, 10–21. https://doi.org/10.1016/j.learninstruc.2014.01.004.

Meyers-Levy, J., & Loken, B. (2015). Revisiting gender differences: What we know and what lies ahead. *Journal of Consumer Psychology*, *25*, 129–149. https://doi.org/10.1016/j.jcps.2014.06.003.

Muhonen, H., Pakarinen, E., Rasku-Puttonen, H., & Lerkkanen, M. K. (2020). Dialogue through the eyes: Exploring teachers' focus of attention during educational dialogue. *International Journal of Educational Research*, *102*, 101607. https://doi.org/10.1016/j.ijer.2020.101607.

Naglieri, J. A., & Rojahn, J. (2001). Gender differences in planning, attention, simultaneous, and successive (PASS) cognitive processes and achievement. *Journal of Educational Psychology*, *93*(2), 430–437. https://doi.org/10.1037/0022-0663.93.2.430.

Oakes, L., & Amso, D. (2018). Development of visual attention. In J. Wixted (Ed.), *The Stevens' handbook of experimental psychology and cognitive neuroscience* (Vol. 4, 4th ed., pp. 1–33). New York, NY: Wiley. https://doi.org/10.1002/9781119170174.epcn401.

OECD (2013). *Skilled for life? Key findings from the survey of adult skills*. Retrieved from doi.org/10.1787/9789264204027-en

Pinto, G., Bigozzi, L., Vettori, G., & Vezzani, C. (2018). The relationship between conceptions of learning and academic outcomes in middle school students according to gender differences. *Learning, Culture and Social Interaction.*, *16*, 45–54. https://doi.org/10.1016/j.lcsi.2017.11.001.

Prediger, S., Kuzu, T., Schüler-Meyer, A., & Wagner, J. (2019). One mind, two languages – Separate conceptualisations? A case study of students' bilingual modes for dealing with language-related conceptualisations of fractions. *Research in Mathematics Education*, *21*(2), 188–207. https://doi.org/10.1080/14794802.2019.1602561.

Prieto, L. P., Sharma, K., Kidzinski, L., & Dillenbourg, P. (2017). Orchestration load indicators and patterns: In-the-wild studies using mobile eye-tracking. *IEEE Transactions on Learning Technologies*, *11*(2), 216–229. https://doi.org/10.1109/TLT.2017.2690687.

Radford, L. (2009). Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics*, *70*(2), 111–126.

Rasmussen, C., Stephan, M., & Allen, K. (2004). Classroom mathematical practices and gesturing. *Journal of Mathematical Behavior*, *23*, 301–323.

Shvartsa, A., & Abrahamson, D. (2019). Dual-eye-tracking Vygotsky: A microgenetic account of a teaching/learning collaboration in an embodied-interaction technological tutorial for mathematics. *Learning, Culture and Social Interaction*, *22*, 100316. https://doi.org/10.1016/j.lcsi.2019.05.003.

Sharma, K., Jermann, P., & Dillenbourg, P. (2014). "With-me-ness": A gaze-measure for students' attention in MOOCs. In *Proceedings of international conference of the learning sciences 2014 no. CONF* (pp. 1017–1022). ISLS.

Van Der Veen, C., & Van Oers, B. (2017). Advances in research on classroom dialogue: Learning outcomes and assessments. *Learning and Instruction*, *48*, 1–4. https://doi.org/10.1016/j.learninstruc.2017.04.002.

Wang, J., Antonenko, P., & Dawson, K. (2020). Does visual attention to the instructor in online video affect learning and learner perceptions? An eye-tracking analysis. *Computers & Education*, *146*, 103779. https://doi.org/10.1016/j.compedu.2019.103779.

Wolfe, J. M., & Horowitz, T. S. (2017). Five factors that guide attention in visual search. *Nature Human Behaviour*, *1*(3), 1–8.

Wolff, C. E., Jarodzka, H., & Boshuizen, H. P. A. (2017). See and tell: Differences between expert and novice teachers' interpretations of problematic classroom management events. *Teaching and Teacher Education*, *66*, 295–308. https://doi.org/10.1016/i.tate.2017.04.015.

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