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Attention to the model's face when learning from video modeling examples in adolescents with and without autism spectrum disorder

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Abstract
We investigated the effects of seeing the instructor's (i.e., the model's) face in video modeling examples on students' attention and their learning outcomes. Research with university students suggested that the model's face attracts students' attention away from what the model is doing, but this did not hamper learning. We aimed to investigate whether we would replicate this finding in adolescents (prevocational education) and to establish how adolescents with autism spectrum disorder, who have been found to look less at faces generally, would process video examples in which the model's face is visible. Results showed that typically developing adolescents who did see the model's face paid significantly less attention to the task area than typically developing adolescents who did not see the model's face. Adolescents with autism spectrum disorder paid less attention to the model's face and more to the task demonstration area than typically developing adolescents who saw the model's face. These differences in viewing behavior, however, did not affect learning outcomes. This study provides further evidence that seeing the model's face in video examples affects students' attention but not their learning outcomes.

KEYWORDS
autism spectrum disorder, example-based learning, eye tracking, modeling, video

1 | INTRODUCTION

Example-based learning is a very effective instructional strategy. Especially when students have little or no prior knowledge of a task, observing a demonstration of a procedure has been shown to be more effective (i.e., higher test performance) as well as more efficient (i.e., higher test performance reached in less time and effort investment) compared to learning by doing (for reviews: Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2014; Sweller, Van Merriënboer, & Paas, 1998; Van Gog & Rummel, 2010). Examples can either be written worked examples in which the entire solution procedure has been written out for students to study, or they can consist of demonstrations (live or on video) by a human model (i.e., modeling examples; for a discussion of similarities and differences in research on worked examples and modeling examples, see Van Gog & Rummel, 2010).

Video modeling examples are increasingly being used in education, since they have become much easier to create and distribute in e-learning environments in recent years. Teachers may create videos for their students and assign them (their own or other teachers') video lessons and video examples as homework (e.g., flipping the classroom; Bergmann & Sams, 2012). Students themselves also seem to actively seek out websites providing such examples while making homework (e.g., Khan Academy) or when learning new skills as part of leisure activities (e.g., "how-to" videos on YouTube) and increasingly share videos themselves (e.g., Lenhart, 2012). Indeed, having students create videos about learning content for other students has been suggested to benefit their own learning outcomes (e.g., Fiorella & Mayer, 2013, 2014; Hoogerheide, Deijkers, Loyens, Heijltjes, & Van Gog, 2016; Hoogerheide, Loyens, & Van Gog, 2014; Spires, Hervey, Morris, & Stelpflug, 2012).

Despite the popularity of video examples among teachers and students alike, surprisingly little is known about design guidelines to optimize the effectiveness of video examples for learning. Of course, there are many general guidelines for designing multimedia learning materials, which may provide some guidance (Mayer, 2014), but relatively few studies have investigated design guidelines specifically for video examples. One important design consideration is whether to show the model's face in the video example or to show only the slides with a voice-over (in case of a lesson-style demonstration supported by slides) or the hands of the model (in case the model is manipulating objects as part of the demonstration).

1.1 | Effects of seeing the model's face and gaze on attention and learning

The design decision of whether or not to show the model's face in a video example will affect students' attention during example study. If the model's face is visible, it is likely to attract students' attention: Other people's faces, and especially their eyes, are known to rapidly and automatically capture our attention (Langton, Watt, & Bruce, 2000). For instance, eye-tracking research on social interactions has shown that, seated opposite a speaker, we look primarily at the speaker's face (as much as 95.6% of the time) and this number does not drop much when we are seated opposite a video of the speaker, so it does not seem to be social convention that is at play here (Gullberg & Holmqvist, 2006). Rather, the reason why we look so much at other people's faces is that their eye gaze provides us with powerful social cues to their intentions. For instance, when someone is walking towards us on the street, we rapidly coordinate with our gaze how we will pass each other (Nummenmaa, Hyönä, & Hietanen, 2009). Gaze-following behavior does not seem to be a purely innate reflex but starts out as a communicative act (as infant research suggests, see e.g., Farroni, Johnson, & Csibra, 2004; Farroni, Menon, & Johnson, 2006; Senju & Csibra, 2008) and becomes highly automated later in life (e.g., Gregory & Hodgson, 2012; Kuhn & Benson, 2007; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002).

However, with the exception of word learning in young children (e.g., Brooks & Meltzoff, 2005; Tenenbaum, Amso, Abar, & Sheinkopf, 2014), there is relatively little research on attention to faces in learning situations (e.g., when studying video modeling examples) and how this affects learning outcomes. It seems reasonable to assume that the very high amount of attention to faces shown in Gullberg and Holmqvist's (2006) study would be unlikely in instructional situations where the speaker is not just relating events but engaging in a demonstration. But to what extent the model's face draws attention in video modeling examples, and whether that hinders, helps, or does not affect learning, is an issue that requires further investigation.

On the one hand, it might hinder learning, because one could argue that any attention devoted to the face would not be devoted to the task the model is demonstrating. In research on animated pedagogical agents in tutoring systems, for instance, it was shown that learners looked at faces of such agents as they would at real humans, fixating often on the face, and in the presence of multiple agents, look at the speaking agent's face (Louwerse, Graesser, McNamara, & Lu, 2009). Because in such tutoring environments, the learning content that the agent is talking about is also present on screen at the same time, this means that any attention devoted to the agent goes at the expense of processing the learning material. Effects on learning were not assessed by Louwerse and colleagues, but this seems to be a plausible explanation for the mixed findings regarding effectiveness of animated pedagogical agents (for a review, see Moreno, 2005).

On the other hand, when the model's gaze shifts provide relevant information to students, it might help learning to see the model's face in the video example. For instance, a recent study addressing this issue of whether or not seeing the model's face affects learning, used video examples in which it was demonstrated how to solve a puzzle problem (Van Gog, Verveer, & Verveer, 2014). Participants (adults) first observed the example, then attempted to solve the problem themselves, saw the example a second time, and made a second attempt at solving the problem. It was found that the instructor's face drew a substantial amount of attention (ca. 23% on the first viewing and 17% on the second viewing), resulting in less attention being paid to the task area compared to a condition in which the instructor's face was not visible. However, this did not hurt learning; the participants who saw the model's face even performed better on the second problem-solving attempt, presumably because the model's gaze allowed them to anticipate the model's actions (Van Gog et al., 2014).

Using a similar design as Van Gog et al. (2014), we recently investigated whether we could replicate this finding using a different task (building a molecule) in a study with university students (Van Wermeskerken & Van Gog, 2017). Students looked at the model's face quite often, though somewhat less than in the Van Gog et al. study (on average ca. 13.3% on the first viewing and 16.6% on the second viewing). This did not negatively affect learning the building procedure, although in contrast to the Van Gog et al. study, it did not facilitate learning either, possibly because performance was very high in both conditions (ca. 39 out of 41 after having seen the example a second time). In addition to the Van Gog et al. study, a knowledge test was administered after each example, for which students had to rely on the verbal explanation, but again, performance on this test was not affected by seeing the model's face.

This study replicated the face visible and face not visible conditions from our prior study (Van Wermeskerken & Van Gog, 2017) with adolescents in prevocational education, using the same molecule building task, to investigate whether or not seeing the model's face would affect learning outcomes in a younger population with a lower level of education. A second and novel question addressed in this study, is whether seeing the model's face would affect attention distribution differently in typically developing (TD) adolescents and adolescents with autism spectrum disorder (ASD), and if so, whether that would affect their learning outcomes.

1.2 | Attention to the model's face and gaze in individuals with ASD

Autism is a neurodevelopmental condition that affects males more than females and is characterized by social-communicative problems and rigid and repetitive behaviors. It is referred to as a spectrum disorder because the severity of symptoms varies widely across individuals (Frith & Happé, 2005). Compared to typically developing individuals who show a preference for looking at faces rather than objects, individuals with ASD have been found to look less at faces (e.g., Riby &

Hancock, 2008, 2009), to perform more poorly on reading emotions from faces and eyes (e.g., Baron-Cohen, Wheelwright, & Jolliffe, 1997), and to look less at the eyes (Jones, Carr, & Klin, 2008; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Riby & Hancock, 2008). Yet, to what extent diminished eye contact is a marker for development of ASD is unclear. For instance, 6-month old infants' looking at eyes (compared to mouth) in a "still-face" paradigm seemed associated with being at risk for autism (i.e., with having an autistic sibling; Merin, Young, Ozonoff, & Rogers, 2007) but was not predictive of later ASD development (Young, Merin, Rogers, & Ozonoff, 2009); indeed, rather than reduced attention to the eye region, more attention to the mouth region seems predictive of later language development and communicative functioning (Young et al., 2009; see also Klin et al., 2002).

Individuals with ASD do not only show atypical eye contact processing but also—and possibly as a consequence—atypical gaze following behavior (Senju & Johnson, 2009) and atypical development of gaze-following behavior (Elsabbagh et al., 2013). Joint attention, that is, attending to an object that another person is gazing at, which is considered an important mechanism in early language learning (Brooks & Meltzoff, 2005; Tomasello & Farrar, 1986), is impaired in children with ASD (Charman, 2003; Gillespie-Lynch, Elias, Escudero, Hutman, & Johnson, 2013). In fact, impaired joint attention may be one of the first signs of ASD (showing before the age of diagnosis; e.g., Elsabbagh et al., 2013; Osterling & Dawson, 1994; for a review on visual attention and early autism see Falck-Ytter, Bölte, & Gredebäck, 2013). Indeed, 10-month-old infants at risk for autism rely on both eye and head information to be able to engage in gaze following, whereas their typically developing counterparts mainly rely on information from the eyes (Thorup et al., 2016).

Nevertheless, similar to TD adults, adults with ASD seem to be susceptible to gaze cues in experimental paradigms (i.e., reflexively following eyes that are looking left or right, therefore being slower to respond to stimuli that require looking in the opposite direction; Kuhn, Benson, et al., 2010). Moreover, whereas one might expect that individuals with ASD would be less susceptible to misdirection via gaze cues in certain magic tricks, in which magicians use their gaze to deliberately distract attention away from their actions, they were actually found to be *more* susceptible to the misdirection (they were somewhat slower at fixating the magician's face and took longer to reallocate attention; Kuhn, Kourkoulou, & Leekam, 2010). This finding is in line with other observations that, even though individuals with ASD look less at faces, they also are slower at reallocating their attention from a (central) stimulus to a different (peripheral) stimulus (e.g., Elsabbagh et al., 2013; Riby & Hancock, 2008, 2009).

Despite difficulties with social interaction, social learning by observing video modeling examples is known to be effective also for individuals with ASD, although this research has mainly focused on children with ASD who learned skills from the video modeling examples that were impaired because of their disorder (e.g., conversation, social skills; see e.g., Delano, 2007; Nadel et al., 2011; Wang, Cui, & Parrila, 2011). An interesting question, however, is whether ASD and TD individuals would differ in how they attend to video modeling examples in which the model's face is visible and whether this affects their learning. The social attention research reviewed above suggests that one might expect individuals with ASD to focus relatively less at the face of the model when studying video modeling examples than TD individuals and to make fewer switches between the model's face and the task area, as they are less inclined to engage in gaze following.

1.3 | The present study

This study investigated (a) whether attention allocation and learning outcomes of TD adolescents are affected by seeing (vs. not seeing) the model's face in the video example and (b) whether adolescents with ASD and TD adolescents differ in how they distribute their attention when studying a video example in which the model's face is visible and whether this leads to differences in learning outcomes. As adolescents were shown the video modeling example twice and performed the test tasks (i.e., molecule building task and knowledge test) after each viewing (cf. Van Wermeskerken & Van Gog, 2017), we also investigated whether adolescents improved from first to second test moment. Finally, exploratory analyses were conducted to investigate whether eye-tracking data is related to task performance (e.g., whether spending relatively more time looking at the task is related to higher performance on the molecule building task or whether spending relatively more time looking at the model's face is related to higher performance on the knowledge test).

2 | METHOD

2.1 | Participants and design

Participants were 59 prevocational education students (the lowest secondary education track in the Netherlands) from two Dutch schools. One of those was a school for adolescents with special needs, from which the participants with ASD were recruited; we requested that the school indicate only students in the ASD group with an IQ of at least >90 according to the school's records for recruitment (to ensure that potentially lower performance in the Face Visible condition of the ASD participants would not be due to lower IQ). Participants were divided into three groups; assignment to groups (b) and (c) was random: (a) ASD, example with Face Visible (n = 20; 18 male; M_{age} = 14.75, SD = 1.37); (b) No ASD, example with Face Visible (n = 19; 8 male; M_{age} = 13.79, SD = 0.42); and (c) No ASD, example with Face Not Visible (n = 20; 9 male; M_{age} = 13.75, SD = 0.44). Due to an administrative error, one participant with ASD was recruited who turned out to have an IQ below 80 according to school records. This participant was excluded afterwards, leaving n = 19 in this condition. Biochemistry was not part of the curriculum followed by these participants at either school, so they were expected to have little if any prior knowledge with regard to the topic of the video examples (i.e., the molecular structure of glutamine).

2.2 | Materials

2.2.1 | Pretest

The short pretest consisted of six questions to test for prior chemistry knowledge participants might have acquired outside school, for example, "what is the abbreviation of carbon?," and "how many bonds can [carbon/oxygen/hydrogen] form?" It was decided prior to conducting the study that data from participants who would answer more than two of these questions correctly would be excluded, which was never the case.

2.2.2 | Video modeling example

The video modeling example showed a young adult male model seated behind a table on which the objects (i.e., molecules and linkages from the Molymod® Organic Teacher Set, Spiring Enterprises Ltd, Billingshurst, UK) were placed in transparent containers grouped by type. The example started with the model explaining some basic characteristics of the objects in front of him, by taking out one piece at a time, showing it to the camera and saying what it was and what its characteristics were (e.g., "This is a carbon atom and carbon can form four bonds."). Subsequently, the model explained and demonstrated how to build the molecule glutamine (i.e., $C_5H_{10}N_2O_3$), which is an amino acid that consists of 20 atoms and 21 bonds. Each step of the building procedure was preceded by a brief explanation (e.g., first make a chain of five carbon atoms; on either end of the chain, one oxygen atom should be attached with the use of two flexible bonds). The video had a duration of 247 s. In the Face Visible condition, the size of the video on the computer screen was 737 × 452 pixels and in the Face Not Visible condition, 737 × 242 pixels (see Figure 1).

2.2.3 | Building test

The building test required participants to build the molecule themselves, using the same materials and starting from the same set-up as shown in the video modeling example (i.e., the same spatial arrangements of the atoms and bonds). Note that—in order not to make the task too easy—both the set-up in the example and that of the participants during the building test contained additional atoms (and bonds) they did not need for building glutamine, both of the kind used in the example (i.e., there were more carbon, oxygen, nitrogen, and hydrogen atoms as well as more bonds than they needed in the containers) and other kinds of atoms (i.e., there were additional containers with phosphorus and sulfur atoms that were not being used).

2.2.4 | Knowledge test

The knowledge test consisted of 20 true/false statements, presented on the computer screen using E-Prime (Version 2.0; Psychology Software Tools, Inc., Sharpsburg, USA), which assessed how much participants remembered from the examples. It consisted of six chemistry statements that required having attended to the model's explanation (e.g., glutamine is an amino acid [true]), 10 statements concerning the molecule glutamine for which having paid attention to the building procedure could suffice (e.g., glutamine contains 4 oxygen atoms [false]), and four transfer statements that were accompanied by images

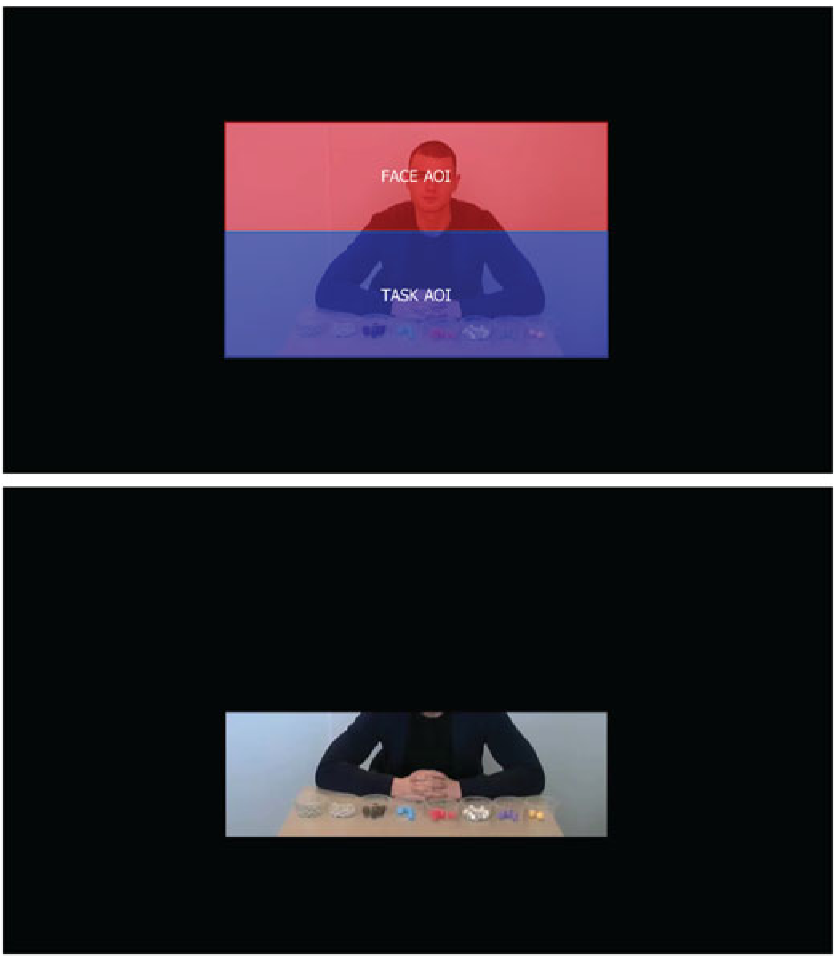

FIGURE 1 Screenshots of the video modeling examples: Face Visible (upper) and Face Not Visible (lower). The face and task areas of interest (AOIs) used in the analysis of the eye-tracking data are indicated in the upper screenshot [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Median (range and median absolute deviation) eye movement data while viewing the example (i.e., relative dwell time in % on face and task areas of interest [AoIs] and transitions between the two AoIs) and performance on the molecule building (0–41) and knowledge (0–20) tests

	TD; Face Not Visible (*n* = 17)	TD; Face Visible (*n* = 13)	ASD; Face Visible (*n* = 11)
Eye movement data[a]			
Face AoI ex. 1 (%)	n.a.	12.12 (5.19–25.06; 5.3)	8.90 (5.19–31.11; 4.0)
Face AoI ex. 2 (%)	n.a.	17.84 (7.14–46.71; 7.1)	9.98 (4.52–24.36; 4.6)
Task AoI ex. 1 (%)	98.18 (62.93–99.53; 4.4)	81.42 (71.50–90.57; 6.4)	89.84 (57.47–93.87; 5.2)
Task AoI ex. 2 (%)	96.00 (52.64–99.66; 7.1)	80.98 (46.34–91.81; 7.9)	88.38 (51.98–95.04; 7.2)
Transitions ex. 1	n.a.	38.0 (24.0–72.0; 13.8)	21.0 (11.0–38.0; 5.8)
Transitions ex. 2	n.a.	39.0 (12.0–56.0; 6.9)	22.0 (9.0–47.0; 8.0)
Molecule building test			
First time	15 (0–35; 10.3)	20 (6–36; 7.8)	24 (7–37; 7.8)
Second time	36 (10–41; 6.4)	35 (14–41; 5.3)	35 (18–41; 5.6)
Knowledge test			
First time	12 (9–14; 0.9)	12 (7–14; 1.8)	12 (8–16; 2.1)
Second time	11 (9–15; 1.6)	12 (10–14; 1.1)	14 (9–18; 2.6)

Note. TD = typically developing.

[a]Ex. 1 and 2 = first and second time the video modeling example was watched; n.a. = not applicable; percentage on Face/Task AoI was calculated by dividing the total dwell time on the AoI by the total dwell time on screen during video modeling example study.

of chemical molecules and asked participants to indicate whether that structure could exist based on the explanation provided in the video about the connections a certain atom could have (e.g., O=C=O can exist [true]).

2.2.5 | Eye-tracking equipment

The video example was presented on a laptop using the SMI Experiment Center software (the screen had a resolution of 1,600 × 900 pixels). While they watched the example, participants' eye movements were registered using an SMI RED-M eye tracker (120 Hz) and the recorded data were analysed with SMI BeGaze software (SMI = Sensomotoric Instruments GmbH, Teltow, Germany).

2.3 | Procedure

Participants were tested individually in a quiet room at their school, which took 30–40 min. They first filled out the pretest on paper. Subsequently, they were seated in front of the laptop and the eye tracking system was calibrated, using a 5-point calibration plus 4-point validation procedure. A calibration was accepted when the accuracy was ≤0.6° in both x and y direction, when this was not accomplished within three calibrations, the best calibration was chosen. After calibration of the system, the video example was shown for the first time; depending on condition, TD participants saw either the full video including the model's face or only the lower part where the task was performed. Participants then moved back to the area where they had completed the pretest to perform the building test. They were given maximally 4 min to complete this test and were not provided with any feedback. After they indicated they had finished or when the 4 min had passed, a picture was taken from the molecule they built to be able to score their performance later on and participants moved back to the laptop to complete the knowledge test (during which the experimenter dissembled the atomic structure). This procedure was then repeated (i.e., calibration, studying the example, and taking both tests). After the experiment, any questions participants had were answered, after which they were thanked for their participation and sent back to their classroom.

2.4 | Data analysis

Unfortunately, 17 participants had to be excluded from the analyses, due to noncompliance with the instructions given during the experiment (ASD with Face Visible: $n = 3$) and technical problems (i.e., inaccurate calibration of >1° after three attempts, ASD with Face Visible: $n = 2$; No ASD, Face Visible: $n = 3$; No ASD, No Face: $n = 1$; tracking ratio [see below] during example viewing <70%,[1] ASD with Face Visible, $n = 3$; No ASD, Face Visible: $n = 3$; No ASD, No Face: $n = 2$).[2] The distribution of the remaining 41 participants across the three groups is indicated in Table 1. Average calibration accuracy in the remaining sample was as follows: first viewing: $M_x = 0.33$, $SD = 0.18$ and $M_y = 0.34$, $SD = 0.16$; second viewing: $M_x = 0.38$, $SD = 0.19$ and $M_y = 0.32$, $SD = 0.18$.

2.4.1 | Eye movement data

To determine participants' dwell time on the screen relative to the total duration of the video modeling example (i.e., tracking ratio), one large

[1]This threshold was chosen as our aim was to study adolescents' attention allocation and shifting of attention during video modeling example study. To be able to draw valid and reliable conclusions based on the eye-tracking data, participants should have attended to the video modeling example for a substantial amount of time.

[2]In addition, due to an error in the settings, 10 participants' eye movements were recorded at 60 Hz instead of 120 Hz. Given that we analyse relative dwell time, this would have very little influence on the data; nevertheless, we tested whether these participants' data deviated from the others in their group, which was not the case. Hence, their data were included in the analyses.

area of interest (AoI) was created that encompassed the entire screen. In addition, two separate AoIs were created that covered the model's face (Face-AoI; 745 × 207 pixels) and the task (Task-AoI; 745 × 248 pixels; see Figure 1).[3]

As there were large differences between participants in the total amount of time spent looking at the screen during the presentation of the video modeling example (i.e., tracking ratio; minimum = 70.3%; maximum = 99.8%; first viewing: M = 94.7, SD = 6.0; second viewing: M = 92.0, SD = 7.4), we corrected the relative dwell times on the AoIs (i.e., Face-AoI and Task-AoI) for the total amount of dwell time on screen. This was done by determining the total dwell time for each AoI and dividing this by the total dwell time on the entire screen (instead of dividing by the total duration of the video modeling example).

In addition, the number of transitions between areas of interest was computed for each participant. A transition was counted whenever at least 50 ms of gaze samples on one AoI was followed by at least 50 ms of gaze samples on the other AoI. Subsequently, the number of transitions from the Face-AoI to the Task-AoI and from the Task-AoI to the Face-AoI were summed.

2.4.2 | Molecule building test performance

Performance on the molecule building test was scored based on the pictures of the molecule that participants had built. Glutamine consists of 20 atoms and 21 bonds (four of which form double bonds). With each element (atoms and bonds) yielding 1 point, a maximum score of 41 could be obtained, in the case that the glutamine molecule was fully rebuilt. Errors in terms of the number of atoms and bonds that deviated from the target molecule (i.e., less than necessary or incorrect additions) were subtracted from this maximum score and so were errors with respect to placement or usage of incorrect bonds or elements (in order to account for errors made in the assembly while having used the correct amount of bonds and atoms). So for instance, if a participant connected the oxygen at the place where a hydrogen atom should have been placed and vice versa, this was counted as two errors because two atoms were not in place.

2.4.3 | Knowledge test performance

Performance on the knowledge test was scored by assigning 1 point per correct answer and summing the number of correct answers (i.e., scores could range from 0 to 20).

3 | RESULTS

Descriptive statistics of the eye movement data as well as performance on the molecule building test and knowledge test are presented in Table 1. Because of violations of the normality assumption (as indicated by significant Shapiro–Wilk tests), data were analysed with nonparametric tests. Differences among groups were analysed with Mann–Whitney U tests and differences from the first to the second example/test moment were analysed using Wilcoxon signed rank tests. For nonparametric tests, r is reported as an effect size with r = .10, r = .30, and r = .50 denoting small, medium, and large effects, respectively (Cohen, 1988).

3.1 | Question 1: effects of examples with versus without the model's face visible (TD)

3.1.1 | Eye movements

In order to assess to what extent participants' attention allocation was affected by seeing or not seeing the model's face, the relative dwell time on the Task-AoI for both viewings was submitted to separate Mann–Whitney U tests. This confirmed our hypothesis that participants in the Face Visible condition spent proportionally less time looking at the Task-AoI than participants in the Face Not Visible condition (first viewing: U = 21.00, z = −3.746, p < .001, r = .59; second viewing: U = 30.00, z = −3.369, p = .001, r = .53). Indeed, on average participants in the Face Visible condition spent 12%–18% of the time looking at the model's face.

3.1.2 | Performance on the molecule build and knowledge test

We first addressed our research question of whether TD adolescents' performance on the molecule building task was affected when learning from video modeling examples in which the model's face was either visible or not visible. Mann–Whitney U tests did not reveal any differences between the Face Visible and Face Not Visible conditions (first build: U = 96.00, z = −0.607, p = .544, r = .11; second build: U = 100.50, z = −0.420, p = .674, r = .08). We then investigated, using Wilcoxon signed rank tests, whether participants improved from first to second test moment, which was indeed the case (Face Visible: z = −2.799, p = .005, r = .78; Face not Visible: z = −3.624, p < .001, r = .88).

With respect to the knowledge test, we first investigated whether performance was affected by seeing the model's face. Mann–Whitney U tests, performed separately for first and second test moment, did not reveal any significant differences in performance between the Face Visible and Face Not Visible conditions (first test moment: U = 108.50, z = −0.085, p = .932, r = .02; second test moment: U = 87.50, z = −0.976, p = .329, r = .18). In contrast to the building test, Wilcoxon signed rank tests showed that performance on the knowledge test did not improve in either condition from the first to the second test moment (Face Visible: z = −0.938, p = .348, r = .26; Face Not Visible: z = −0.190, p = .849, r = .05). Finally, we checked whether performance was above chance (>50%) for each condition and each test using one-sample t tests (Bonferroni adjusted α = .0125, given four comparisons). For the Face Visible condition these analyses revealed that performance was above chance only for the second test (first test: $t[12]$ = 2.33, p = .038; second test: $t[12]$ = 6.04, p < .001). For the Face Not Visible condition, performance on both tests was above chance (first test: $t[16]$ = 6.08, p < .001; second test: $t[16]$ = 3.67, p = .002).

[3]The AoIs were a few pixels larger than the size of the video on the screen, so that they included all of the video.

3.2 | Question 2: face processing and learning in TD versus ASD adolescents

3.2.1 | Eye movements

In order to address our research question how adolescents with ASD and TD adolescents distribute their attention when studying a video example in which the model's face is visible, relative dwell times were computed (see Table 1). This revealed that, on average, adolescents with ASD looked less at the model's face than TD adolescents, which was confirmed, but only for the second viewing, by a Mann–Whitney U test conducted on relative dwell time on the Face-AoI (first viewing: U = 42.00, z = −1.709, p = .087, r = .35; second viewing: U = 35.00, z = −2.115, p = .034, r = .43).[4] A similar analysis but now for Task-AoI, revealed that adolescents with ASD looked significantly more at the Task-AoI during both viewings (first viewing: U = 32.00, z = −2.288, p = .022, r = .47; second viewing: U = 37.00, z = −1.999, p = .046, r = .41).

We ran Wilcoxon signed rank tests to explore whether adolescents with ASD and TD adolescents spent relatively more or less time looking at the task or the instructor's face from first to second viewing. These analyses revealed that only for the TD adolescents was there an increase in relative dwell time at the instructor's face (Z = −2.481, p = .013, r = .69). However, this was not accompanied by a decrease in dwell time at the task (p = .152). For the adolescents with ASD, no differences were observed (p's ≥ .131).

In addition, we investigated how often adolescents with ASD and TD adolescents switched between the Task and Face-AoI. To this end, the number of transitions for each viewing was submitted to a Mann–Whitney U test, which revealed that for both viewings adolescents with ASD made fewer transitions than TD adolescents (first viewing: U = 14.00, z = −3.334, p = .001, r = .68; second viewing: U = 25.00, z = −2.698, p = .007, r = .55). Wilcoxon signed rank test revealed no differences in number of transitions between the first and second viewing for both groups (both p's ≥ .249).

3.2.2 | Performance on the molecule build and knowledge test

We first addressed the question of whether there were any performance differences on the molecule building test between the ASD and TD adolescents. Mann–Whitney U tests for each separate build did not reveal any differences (first build: U = 55.50, z = −.929, p = .353, r = .19; second build: U = 60.50, z = −.642, p = .521, r = .13). Secondly, it was investigated whether adolescents with ASD improved from first to second build (for TD individuals, this was already established, see previous section), using a Wilcoxon signed rank test. Indeed, building test performance of adolescents with ASD improved with large effect size (z = −2.936, p = .003, r = .89).

Regarding the knowledge test, we first investigated whether there were differences in performance between ASD and TD adolescents. Mann–Whitney U tests did not reveal any significant differences in performance on either test moment (first test moment: U = 70.50, z = −.059, p = .953, r = .01; second test moment: U = 61.00, z = −.615, p = .569, r = .13). A Wilcoxon signed rank test revealed that the adolescents with ASD did not significantly improve on the knowledge test from the first to the second test moment (z = −1.565, p = .118, r = .47), similar to the TD adolescents (see above). Finally, we assessed whether performance was above chance (>50%), using one-sample t tests (Bonferroni adjusted α = .025 given two comparisons). These analyses revealed that performance was only above chance for the second test (first test: t[10] = 2.08, p = .065; second test: t[10] = 3.38, p = .007).

3.3 | Exploratory analyses: relation between eye movement data and performance

To explore the relation between eye movement data and performance outcomes, we determined Spearman correlations between relative dwell times and performance on the molecule building and knowledge tests, and between the number of transitions and performance on the molecule building and knowledge tests, separately for each viewing and for the ASD and TD adolescents. This only revealed a significant positive correlation between the number of transitions during the first viewing of the video modeling examples and the score on the molecule build for the ASD adolescents (r_s = .704, p = .016; more transitions were associated with higher performance on the molecule build) but not for the second viewing (r_s = .130, p = .704). All other correlations were nonsignificant (all r_s's ≤ .423, all p's ≥ .150).

4 | DISCUSSION

Previous research has found mixed findings regarding the effectiveness of seeing a model's face when learning from video modeling examples. Aim of this study was twofold. First, we aimed to see whether we would replicate the findings from our previous study with university students (Van Wermeskerken & Van Gog, 2017) in a younger population with a lower level of education. Second, we addressed the novel question of whether seeing the model's face would differentially affect attention distribution of adolescents with ASD and TD adolescents and whether this would affect their learning outcomes.

With respect to the first aim, we replicated our previous findings in this adolescent population, by showing that their learning was not affected by the presence or absence of the model's face, even though they spent proportionally less time looking at the task area when the model's face was visible. These findings (and those from our prior study; Van Wermeskerken & Van Gog, 2017) are in contrast with the findings of Van Gog et al. (2014) who found a beneficial effect of seeing the model's face after having seen the example twice. However, they are in line with other studies that did not show effects of seeing a model's face when learning from Web lectures or from lecture-style video examples (Kizilcec, Bailenson, & Gomez, 2015; Ouwehand, Van Gog, & Paas, 2015).

The fact that seeing a model's face in a video modeling example affects learners' allocation of attention but does not negatively affect their learning outcomes suggests that learners are able to efficiently

[4]Analyses on relative dwell times were repeated using a smaller Face-AoI (i.e., 320 × 207 pixels) to rule out that participants with ASD looked next to, instead to at, the model's face. These analyses yielded the same outcomes (first viewing: U = 45.00, z = −1.535, p = .125, r = .31; second viewing: U = 33.00, z = −2.231, p = .026, r = .46).

distribute their attention between the model and what he or she is demonstrating, when the model's face is visible. The question remains though, why we did not replicate the findings of Van Gog et al. (2014) that seeing the model's face can positively affect learning with the present materials in either a university student or adolescent sample. This might have to do with the task that was demonstrated. Because the molecule-building task required many steps (41) with small components that had to be attached to each other, the model was looking down at the objects a lot (i.e., up to 78% of the video). In the Van Gog et al. study, the model demonstrated a 15-step puzzle problem in which objects were moved to individual locations; thus, there may have been more opportunity for joint attention (i.e., the model's gaze cueing learners regarding the model's next action). In addition, the molecule was continuously visible. Hence, in the case that learners got distracted by the model's face, they could catch up with the missed step(s) by attending to the state of the molecule at that moment. Therefore, future research should look more specifically into the role of gaze guidance to establish beneficial effects in video modeling examples.

With respect to our second aim, it was hypothesized that, given that individuals with ASD are less inclined to look at faces and engage less in gaze following (Riby & Hancock, 2008, 2009), adolescents with ASD would look less at the face of the model when studying video modeling examples than TD adolescents and would make fewer switches between the model's face and the task area. These hypotheses were confirmed: Adolescents with ASD spent proportionally less time looking at the model's face (though this was only significant during the second time the example was studied) and proportionally more time looking at the task area than TD adolescents (i.e., during both viewings). In addition, adolescents with ASD switched less often between the face of the model and the task area than TD adolescents, which provides tentative evidence that they engaged less in gaze following than TD adolescents. However, although attention allocation differed between adolescents with ASD and TD adolescents, this did not impact their learning outcomes (as was to be expected given that seeing or not seeing the model's face did not affect learning either for TD adolescents). These findings are in line with previous observations that video modeling exmaples are an effective learning tool for adolescents with ASD (e.g., Nadel et al., 2011) and extend these findings to a procedural learning task.

In an attempt to get more insight into the attentional mechanisms that might explain learning from video modeling examples, we conducted exploratory analyses in order to investigate whether eye-tracking measures (i.e., relative dwell time and number of transitions) were related to learning outcomes (i.e., knowledge test performance and molecule build performance). These analyses revealed that ASD adolescents who made more transitions between the model's face and the task area also showed higher performance on the molecule building test but only at the first viewing of the example. This finding suggests that increased attention shifting might be associated with better procedural learning in ASD participants. One reason that this finding was not revealed for the second viewing might be that performance for the molecule build was relatively high after the second example study. Yet, given the small sample size and the absence of this association between attention shifting and molecule build performance for the TD adolescents, caution is warranted in interpreting this finding and future research is needed to corroborate this finding in order to uncover whether and, if so, what attentional mechanisms are associated with learning outcomes.

This study has some limitations. First, we had some technical difficulties with eye tracking in the school environment with this adolescent prevocational education population (which is understudied in educational research), resulting in small sample sizes in the analyses. Power analysis revealed that we had enough power (0.80) to detect medium- to large-sized effects ($r \geq .43$) with our sample with a one-tailed test and $\alpha = .05$. Consequently, our findings, especially with respect to test performance, should be interpreted with caution; note though that a study with (TD) university students with larger sample sizes did not show any effect of seeing the model's face on learning outcomes (Van Wermeskerken & Van Gog, 2017).

Second, we only included high-functioning adolescents with ASD (i.e., IQ ≥ 90, according to school records). Hence, future research should investigate whether the current findings can be generalized to a broader range of intellectual ability in ASD.

It would be interesting for future research to further investigate whether or not there are differences among learners with ASD and TD learners in their attention distribution and learning gains when learning from online video. Most research on instructional technology, such as video modeling examples, for individuals with ASD, focuses on (improving) skills that are impaired by their disorder, not on whether or how their disorder impacts learning in school subjects from e-learning materials. For instance, it would be interesting to see whether differences between learners with ASD and TD learners would arise when social cues provided by the model (e.g., gaze and gesture) are necessary to ensure that learners understand what he or she is referring to or to ensure that they attend to the relevant information in a timely manner. For TD adolescents, social cues might help them switch their attention adaptively and rapidly between the model's face and the relevant information (see e.g., Ouwehand et al., 2015), which might foster learning. On the contrary, adolescents with ASD might encounter difficulties with rapidly following such social cues (cf. Kuhn, Benson, et al., 2010), which might perhaps negatively impact their learning outcomes.

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