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## APPROACH TO TEACHING GEOMETRY TO DYSPRAXIC STUDENTS

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*The aim of this contribution is to present an overview of an approach to teaching geometry to dyspraxic fifth and sixth-grade students. These students face some important difficulties in using geometrical instruments (ruler, compass, set square) with required precision. We've developed a dyadic work system, based on the preserved skills of dyspraxic students, to allow them to study geometry without drawing geometric figures being an obstacle. We present this work system, its theoretical background, an implementation in a pencil-and-paper environment and the possibilities offered by a human interaction simulator to contribute to teaching geometry to dyspraxic students.*

### INTRODUCTION

In French primary school and at the beginning of secondary school (students aged 9-12 years), the teaching and learning of geometry is based primarily on situations requiring the use of instruments (ruler, compass and set square) in a pencil-and-paper environment. Tracing with instruments to reproduce, to represent or to construct geometric figures is an injunction of the school curriculum, and is supposed to contribute to the conceptualization of geometric concepts. However, this teaching method, which uses manipulatives, is not suitable for all students, and in particular for students with dyspraxia, as they cannot perform the skilled movements necessary for such academic tasks: their motor performances are slower, less accurate and more variable (Elbasan & Kayihan, 2012). These students invariably fail to complete tasks in geometry, whereas they do have the core abilities – reasoning, language and memory – that would otherwise enable them to conceptualize geometric notions.

Our research aims at proposing alternative ways of teaching geometry, accessible to all students, and in particular for those who have difficulties in manipulation in order to meet the objectives of the geometry curriculum. In the first part of this paper, we present a dyadic system for teaching geometry considering the handicap of dyspraxic students and their preserved capabilities. We next present an example of an implementation of this work system in a pencil-and-paper environment with two students (dyspraxic student and standard student). Finally, we present the possibilities offered by a human interaction simulator to contribute to teaching geometry to dyspraxic students.

### A WORK SYSTEM FOR TEACHING GEOMETRY

The dyadic system (Petitfour, 2016) is based on the joint activity of two students, an *instructor* and a *constructor*, who interact to solve a geometric construction problem. This system is anchored in a conception of learning as a social phenomenon (Vygotsky, 1978): the formation of mathematical concepts is carried out through social interactions, in joint work around the resolution of a problem. The work takes place through free exchanges on possible construction techniques, the implementation of a chosen technique in the “instructor-constructor dyad” and discussions on the validity of what is produced. This dyadic work system is based on the language dimension of geometric activity, in order

to capitalize the preserved capabilities of dyspraxic students. It aims to replace instrumented action situations for dyspraxic student with situations that are as close to action as possible, but without any actual action, while producing similar effects in terms of geometric learning.

The construction proceeds as follows. The instructor expresses his/her *prior intention* (Searle, 1983) through language instructions to the constructor, accompanied by gestures. The constructor carries out the instrumented actions requested while the instructor observes the concrete implementation and obtains precise feedback. Let's specify the language, gestures and feedback specific to this work.

### Geometric technical language

The instructor uses a technical language (Petitfour, 2016) to formulate his/her plan for the instrumented actions. In the field of geometry, the technical language relates to the use of instruments in connection with the geometric properties they convey. It is used to express the relationship between geometric lines and a given instrument in order to produce a new line. For a given instrumented action, the instructor first mentions the instrument to be used, then gives its position by describing the relations between the instrument and graphic objects already present and finally indicates the location of the line. For example, drawing a circle of center A and radius AB (geometric language) corresponds to the following instructions in technical language: take the compass, put the point of the compass on point A and the pencil lead on point B, draw the circle. This language must not be confused with “manipulative language” that expresses corporeal action (e.g., “Hold the compass by the top, not by the legs”, “Press more on the point of the compass than on the pencil lead”).

### Mathematical gestures

Following McNeill (1992) in that gestures, together with language, help constitute thought, we propose to associate with oral language the use of mathematical gestures, i.e. any body movement, spontaneous or deliberate, carrying a meaning related to mathematics. In geometry, deictic gestures (Figure 1a) can, for example, link elements of the drawing (straight line, point) with parts of the instrument (side or vertex of the right angle of the set square); mimetic gestures (Figure 1b) can evoke the handling of the instrument (turning the compass); iconic gestures (Figure 1c) can represent a geometric relationship or a geometric object (triangle).

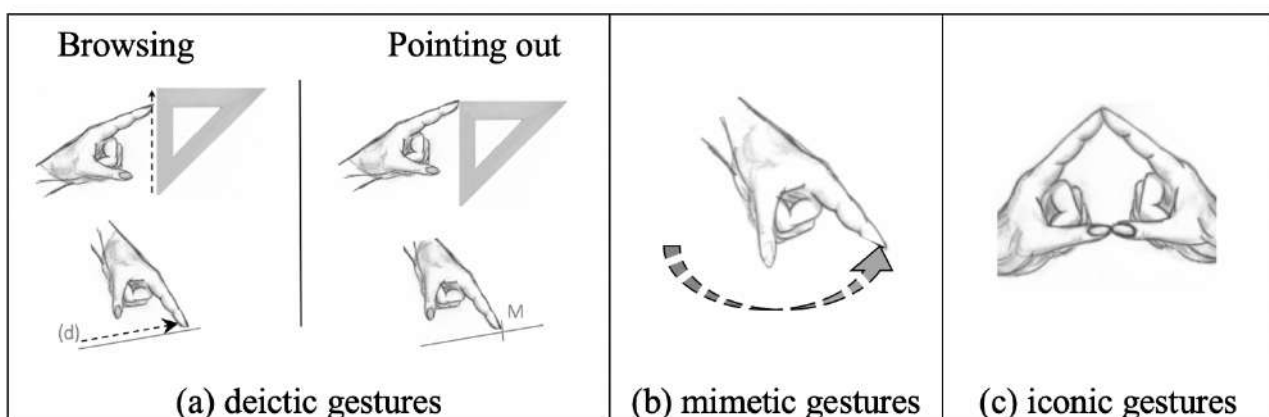


Figure 1: Example of mathematical gestures

These mathematical gestures can be produced by dyspraxic students: they require less precision than actions and they offer the advantage of expressing the planned drawing without leaving a graphic

trace. Moreover, for the instructor, producing gestures help to preserve the role of bodily and kinesthetic experience in mathematical learning, as highlighted in various studies (e.g. Nemirovsky, 2003; Arzarello et al., 2009).

### Feedback

The constructor follows the instructor's instructions: he/she takes the chosen instrument, positions it as requested and draws the required line. When he/she detects ambiguities in the instructor's instructions, he acts in the "least likely" way to help him/her remove the implicit meaning. In this way, the constructor needs to pay attention to the validity of the instructions for obtaining a correct figure, i.e. one constructed without the "guesswork" of using the instrument (such as positioning the ruler perceptually to draw a right angle).

By working in pairs, dyspraxic student (in the role of the instructor) can experience the instrumented actions he/she is planning by observing them, without worrying about their manipulative characteristics. He/she also benefits from feedback that is consistent with his/her instructions, on which he/she can base his/her thinking.

In the following section, we illustrate this dyad work system by analyzing an implementation in a pencil-and-paper environment with two sixth-grade students (dyspraxic student and standard student)

### EXAMPLE OF AN IMPLEMENTATION

Marion is an 11-year-old student diagnosed with visuo-spatial dyspraxia. Her psychomotor assessment demonstrated an immature spatial organization and difficulties with digital untying and oculomotor co-ordination. She has always had difficulty writing and drawing geometric figures with instruments at school. Despite her many attempts, her attention and her efforts, she was never able to achieve the required precision. This is illustrated by the comments made by her mathematics teacher in the following extract from an assessment (Figure 2). The use of ruler and set square act as a barrier between what she knows, what she wants to draw and the act of drawing. She indeed knows how to draw the symmetry of a point or a straight line with respect to a straight line, but when she draws with the instruments, she places the set square imprecisely, the instrument moves when she draws, etc.

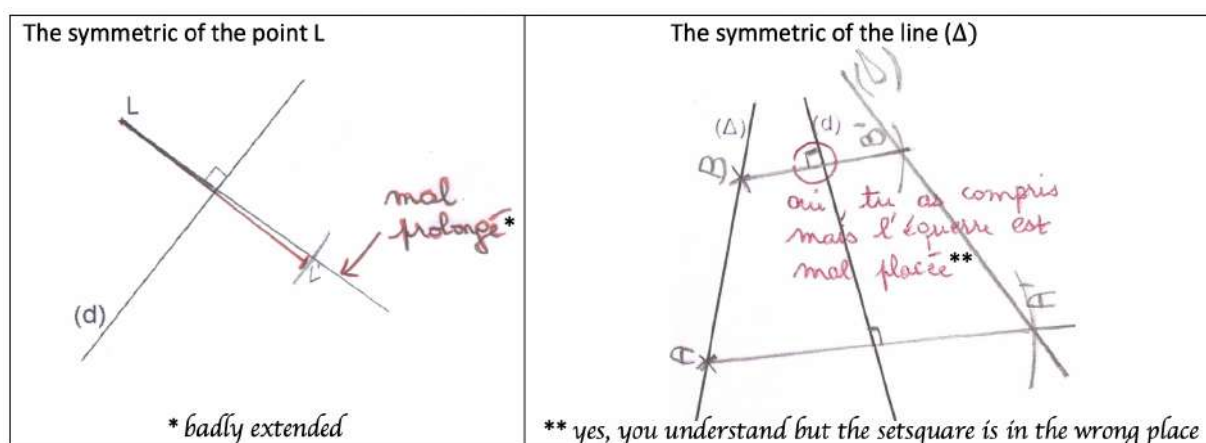


Figure 2: Marion's work

We report on the implementation of the dyadic work system that we tried out a month and a half later with Marion and Bonnie, a student in her class.

Given Marion's visuo-spatial difficulties, the instructions were given orally so as not to add a reading task to the proposed geometric task (Figure 3). In addition, the two straight lines were differentiated by color (the axis of symmetry was in red) and the starting figure was presented using gestures (browsing the straight lines, pointing to the points) to accompany the speech.

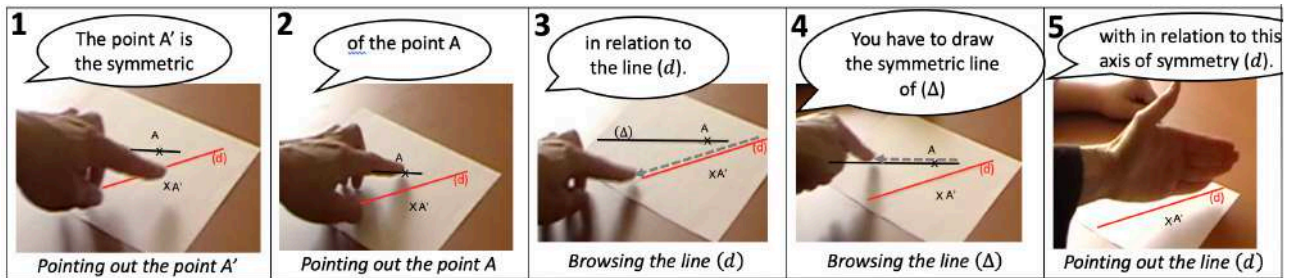


Figure 3: Instructions given to Bonnie and Marion

Bonnie and Marion both immediately announced that they knew how to do it, as soon as the instructions had been given. Bonnie gave a drawing technique (Tb) that involved extending the line ( $\Delta$ ) to its point of intersection with the axis of symmetry and then drawing the line through this point and point  $A'$ . Marion reacted by challenging this technique: "But actually, Bonnie, you can draw your line wherever you like, you can put it like this, like this, like this, so that it touches the point", pointing with her hand to different directions of the line that pass through the point of intersection that Bonnie was proposing to construct. Marion then gives her drawing technique (Tm), which involves drawing the symmetrical line of a second point on the line ( $\Delta$ ) in order to draw the line that passes through this symmetrical point and the point  $A'$ .

Both drawing techniques are shown in Figure 4 with the speech and gestures produced by Bonnie and Marion during their interactions.

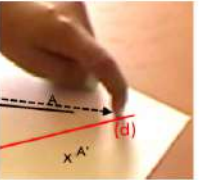
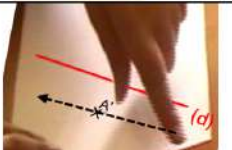
Technique proposed by Bonnie (Tb)	Technique proposed by Marion (Tm)
<p>You take a ruler, you extend the line to the axis of symmetry</p>	<p>I say we should put a second point at the bottom of the line, even if it's infinite, on the represented line</p>
<p>Then you take the ruler, you draw a line passing by <math>A'</math> and the point of intersection</p>	<p>and you do the symmetrical</p>
	<p>then you connect the two dots</p> 

Figure 4: Two different construction techniques

Neither Bonnie nor Marion mentions point  $A'$ , but they both point to it and run their fingers over it as they trace the symmetrical line they are considering. In this way, the two students can reflect together

on the geometric problem they have been given, without any language barriers limiting their reasoning: it's difficult to focus on using geometric language properly while at the same time exploring and explaining possible solutions to a problem. The obstacles associated with the layout that Marion would encounter if the initial discussions to solve the problem were based on instrumented layouts were also ruled out, given her disability.

Both techniques (Tm and Tb) will be put to the test. The following four vignettes (Figure 5) trace the beginning of the interactions between Marion, the instructor, and Bonnie, the constructor.

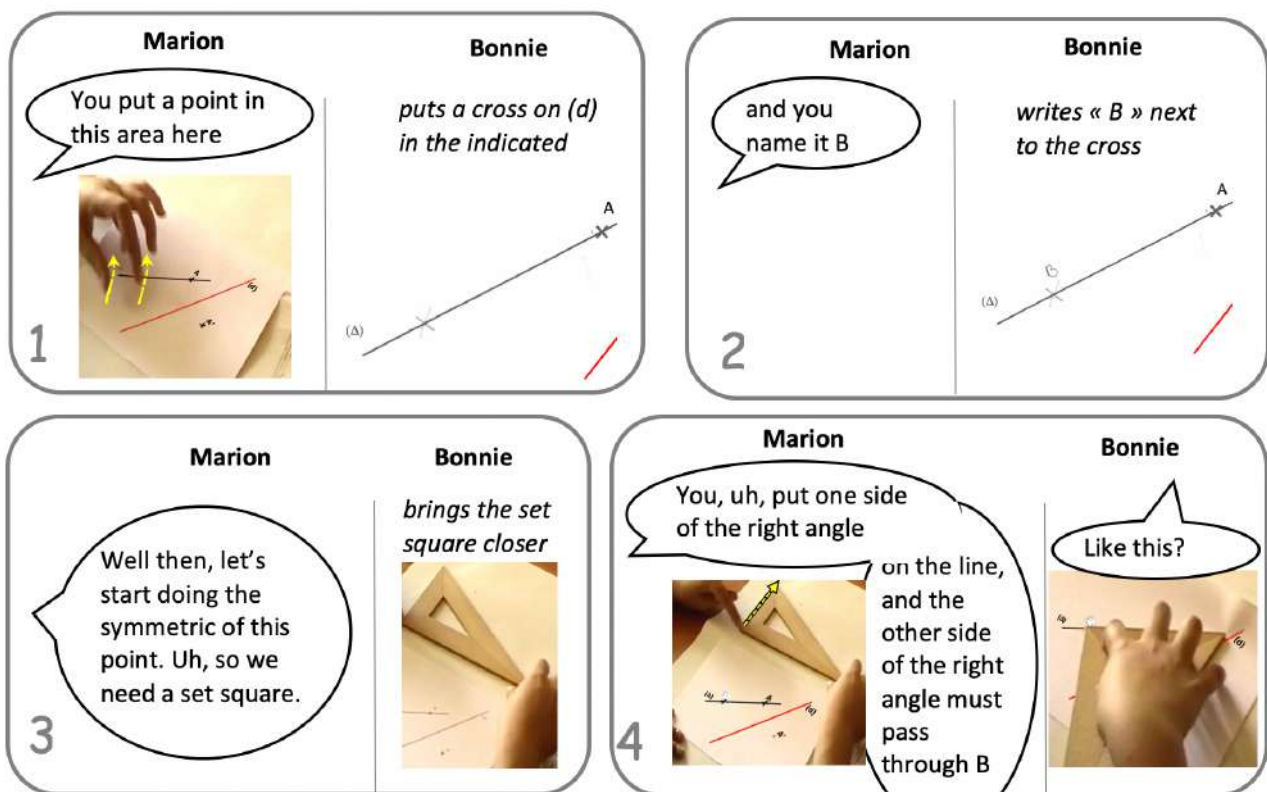


Figure 5: Carrying out the construction

Marion gestures to the part of the line ( $\Delta$ ) on which she wants Bonnie to place a point (Vignette 1). As well as the necessary indication of the line to which the requested point must belong, she is probably making sure that the point chosen is a long way from point A to allow precise drawing. In formulating her technique, she had in fact specified that the second point should be "at the bottom of the line" (Figure 4, Tm).

Marion then names the introduced point "B" (Vignette 2), and announces her intention: to make the symmetrical point of point B (Vignette 3). This information can help Bonnie to anticipate the drawings, if necessary correcting the position of point B on the line ( $\Delta$ ) so that its symmetrical point does not leave the support sheet. She can also help her to give Marion feedback on her instructions ("do the least likely thing"). After asking for the set square, Marion specifies its position: "one side of the right angle on the line and the other side of the right angle must go through B" (Vignette 4). The instruction was incomplete: Marion hadn't specified which straight line she was talking about (the axis of symmetry (d)) or pointed to it with her finger. Bonnie then suggests a position that corresponds to the instruction given, by choosing the line ( $\Delta$ ) and asks Marion if this is appropriate. Marion can then add the missing detail if this was not the position she had in mind.

The presentation of this short extract from the interactions between Bonnie and Marion suggests a certain potential of the dyadic working system: the two students can get involved in solving an instrumented construction problem, applying their knowledge and developing it. For the dyspraxic student, the obstacle of handling instruments is removed, giving way to geometric work.

Following this initial experiment outside the classroom, we continued our research in collaboration with teachers by implementing the dyadic system in the context of the class, adapting it to its constraints, so that it produced the expected effects in terms of geometric learning for all the students. We observed that it was not easy for some of students in the role of instructor to use the technical language and that the feedback from some of students in the role of constructor was not always appropriate. This led us to imagine a dyadic work in the digital environment, using an avatar, so that the students can learn the technical language, the rules of the dyad and the correct use of the instruments. We give an overview in the next section.

### GIVING INSTRUCTIONS TO AN AVATAR

In collaboration with Fabien Emprin, we used the Virtual Training Suite<sup>15</sup> software as a human interaction simulator in an exploratory study (Emprin & Petitfour, 2021). With this software, reality is rendered by the setting of a classroom in which the avatar is installed as if next to the student instructor (Figure 6, left), and by videos of the hands of a person carrying out the required actions (Figure 6, right).

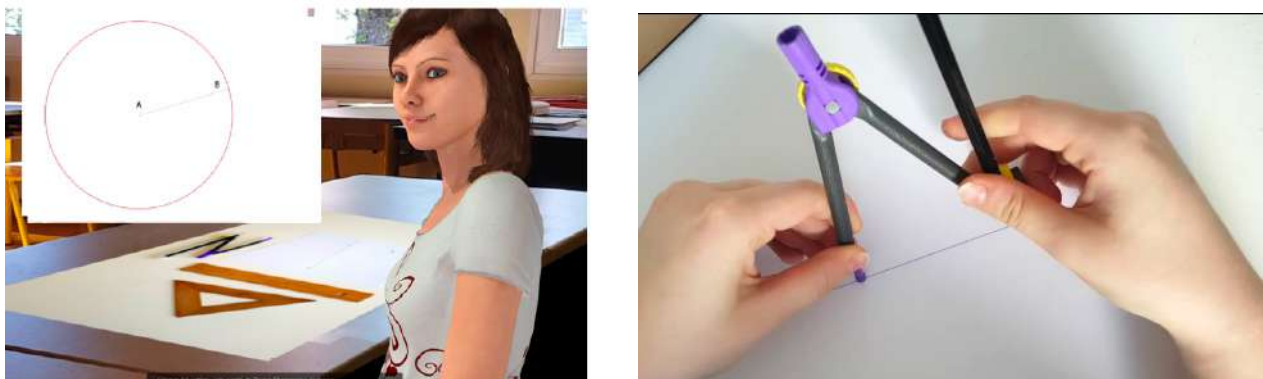


Figure 6: The avatar in the human interaction simulator

The simulator proposes five elementary instrumented actions (Figure 7) for which the instructor must get the avatar to produce the red line on the starting drawing. Each of the five drawings corresponds to an instrumented action, that is, an action that leads to the production of a line with an instrument (non-graduated ruler, set square or compass). A combination of several different types of actions allows to construct a complex figure.

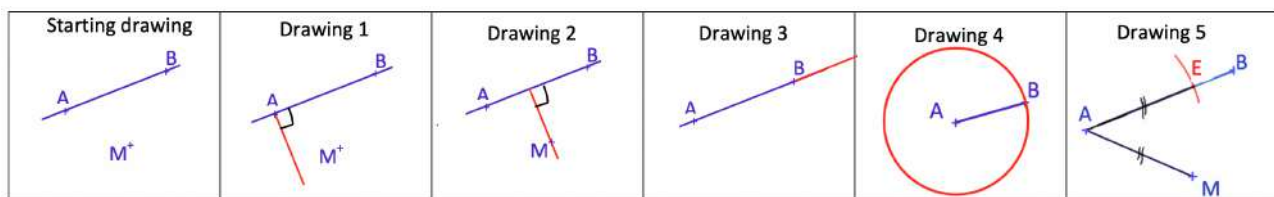


Figure 7: Elementary instrumented actions

<sup>15</sup> <https://seriousfactory.com/virtual-training-suite/>

Once a drawing selected, the student has to choose which instrument to use among ruler, set square and compass, in order to obtain the red line from the starting figure (Figure 8, step 1). He/she can then see the hand of the avatar taking the requested instrument in video. Four or five positioning formulation of the chosen instrument in relation to the geometric objects present are then proposed (Figure 8, step 2). One is valid, and the others are incomplete or not precise enough.

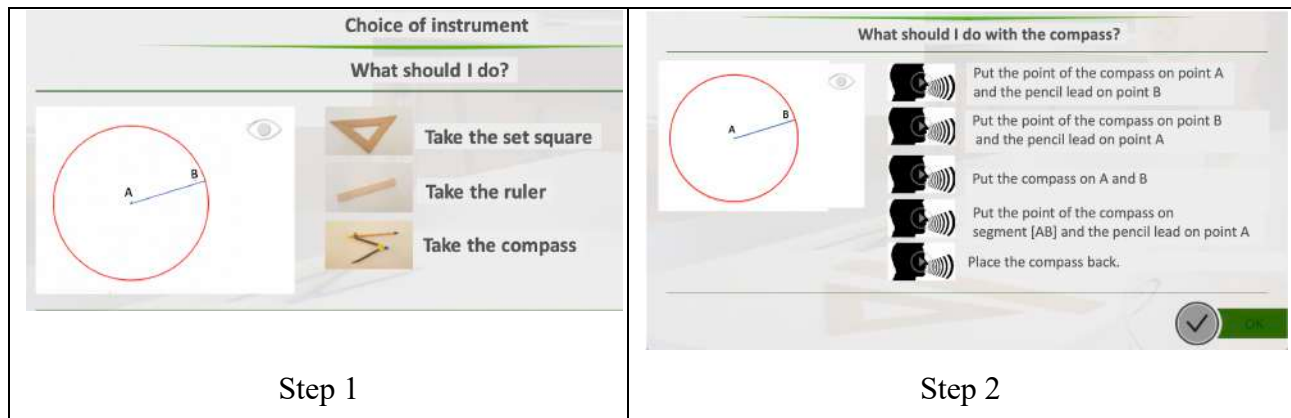


Figure 8: Example of choices proposed by the simulator

The student selects the instruction that seems to be appropriate, and then watches a video of the avatar's hands performing the requested positioning, while observing the "least likely" rule. The student can go back on his/her decision or confirm the avatar to carry out the drawing. In the latter case (step 3), he/she sees a video of the avatar's hands making a drawing from the position of the chosen instrument. The avatar compares the drawing produced with the expected drawing. If it is not correct, the student makes another proposal, if it is correct, the avatar formulates the drawing produced in geometric language (for example for the drawing 4 of Figure 7, the avatar says "Well done, you've correctly drawn the circle with center A and radius AB").

Computer simulation removes certain aspects of human interaction, which can have positive effects. Indeed, the fact that the computer shows no impatience or judgement can help to instill confidence in the student, particularly if he/she has a disability. He/she can think at his/her own pace, and benefit from interactions with the avatar that are less emotionally charged than they might be with a peer. Moreover, because the computer does what it's told without over-interpreting, the student can better understand the need to be explicit in his/her instructions. There are a few drawbacks to using the simulator, however. We had to abandon the development of the gestural dimension for the instructor to accompany the language: gestures cannot be considered by the software used, only language instructions can. What's more, the student's freedom of expression is restricted, since he/she has to select from a finite list.

Our first experiment was carried out as follows. The teacher began with focusing the whole class on the functions of the set square and the compass, then to the technical and geometric terms to be used, associating them with gestural exploration (see Figure 1a). The students then each worked freely with the software (student–instructor and avatar–constructor dyad), while the teacher observed their work. At the end, the teacher consulted a summary of the activities for each student memorized by the software: the number of (in)correct choices of formulation and instrument, the number of times the student (not) correctly anticipated that the positioning of the instrument was (in)valid; the number of times the student correctly identified that he/she had reached (or not) the goal. Next, a discussion led

by the teacher highlighted the rules of the dyad work system (role of the avatar as constructor and language to be used by the instructor). The students then practiced the five elementary instrumented actions (Figure 7) in the pencil-and-paper environment, alternating between the roles of instructor and constructor. They then worked on other geometric construction, taking the avatar's responses, and some actions, as a model for their own behavior. An exploratory study of the contribution of the human interaction simulator thus designed to teach geometry to dyspraxic students led us to establish a proof of concept (Emprin & Petitfour, 2021, 2023). Our initial experimental results indicate that alternating student-avatar and student-student dyads is of interest for teaching geometry to dyspraxic students, but also for any student. These results still need to be confirmed by further experiments.

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