# Fostering Reading Comprehension of Learning Tasks with Pictorial Symbols: A Qualitative Study of the Subjective Views and Reading Paths of Children with and without Special Needs

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## Abstract

*How can barriers in reading be reduced? Adding symbols to assignments could be one possibility for enhancing readability and, therefore, providing students with poor reading skills with access to learning material. This qualitative interview and eye-tracking study aims to acquire a first insight into how students rate and perceive the addition of symbols to texts. Students with special educational needs (N = 6) and without special educational needs (N = 6) participated. All students worked on tasks that were designed as an introduction to fractions. The study shows that the participants rated the additional symbols positively and utilized them without a prior explanation. Furthermore, the symbols were mainly used by the students to gain a holistic understanding of the assignments.*

## Introduction

Written language is highly important in democratic societies. The ability to read is a precondition for social participation; for example, it is needed to obtain access to all kinds of information. Children with special needs often have difficulties with reading. Surveys from different countries and areas show that there are many children with physical, learning, cognitive or developmental disabilities who are not able to understand information presented in written language (Erickson & Geist, 2016; Scholz, Wagner, & Negwer, 2016). These students experience barriers in many areas. To reduce these barriers in school and society, access to written information must be facilitated.

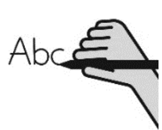
Scholz, Dönges, Dechant, & Endres (2016) differentiate between three forms of making information more accessible: (1) text (linguistic) simplifications, that is, the use of easy-to-read language; (2) text augmentation using pictures (for example, pictorial symbols) to convey the meaning of certain words within a text to enhance understanding; (3) text substitution, which involves strategies that substitute the whole meaning of written language with videos or photographs depicting the whole meaning of a sentence or phrase. The first two approaches will be illustrated in the following paragraphs in more detail.

Information can be made more accessible by applying easy-to-read language. In this study, the German rule set for easy-to-read language (Netzwerk Leichte Sprache, 2006) is used. Easy-to-read language was established to facilitate understanding for people with disabilities in everyday life. It is used to simplify manifestos or newspapers in order to support participation in society. So far, the guidelines for easy-to-read language have not been verified scientifically. They show several similarities to empirically based linguistic simplification rules, such as the Hamburger Modell (Langer, Schulz von Thun, & Tausch, 2011) and refer to the word, sentence, text, and design levels. Concerning the word level, they specify that compound words should be written with a hyphen in order to make the word's structure easier to recognize for the reader. For example, the word "basketball" would be written as "basket-ball". The guidelines also emphasize that only one statement should be made per sentence. The sentence *Write down the fractions according to their size* would thus be replaced by the two sentences: *Write down the fractions. Start with the largest*. The easy-to-read guidelines furthermore stress the importance of personally addressing the reader and using a well-structured layout. For example, all words that build a meaningful unit should be written on one line. Of course, the described rules do not claim to be complete. They have a rather illustrative function as they show the benefits of this concrete and easily applicable set of guidelines.

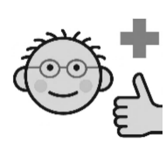
Another possibility for enhancing readability is the use of symbols. According to Detheridge & Detheridge (2002), a symbol can be defined as a graphical image conveying a single idea or concept. This means that a symbol is usually linked to a single word. As pictorial symbols convey the same ideas as words, it can be assumed that they make texts more accessible for students who have difficulties with reading (Hurtado et al, 2014). Thus, the use of the word symbol in this study is different to the widespread idea of symbols as arbitrary signs (Schnotz, 2005).

Symbols can be divided into different categories (Detheridge & Detheridge, 2002). Transparent or guessable symbols possess an obvious connection to their referent. They usually represent nouns or verbs and show several similarities to the object or activity they refer to. The symbol for the word headphone is an example of this category (Figure 1). There are also translucent or learnable symbols. They are not immediately recognizable, but the link between the image and its referent can be relatively easy understood and remembered (Figure 1). In contrast to transparent and translucent symbols, opaque symbols need to be learned. Even though these symbols are created from elements that are connected with the object or idea, the reader needs some explanation of how the image relates to the meaning. The complexity of these symbols results from the more complex vocabulary base.

Headphone (transparent)




Write (translucent)



health (opaque)

**Figure 1. Examples of symbol categories**

Note: The symbols are taken from the Metacom symbol system (Kitzinger, 2015).

The combination of both symbols and easy-to-read language is one possibility for making written information easier to access. Based on the integrated model of text and picture comprehension by Schnotz (2005) and the cognitive theory of multimedia learning by Mayer (2009), we expect symbols to have a positive influence. Both models assume that pictorial and verbal information is processed in two different channels in the brain. When both words and pictures are presented, both channels are used and the limited capacity of the working memory increases.

Empirical data on whether symbols facilitate the comprehension of texts are very limited, ambiguous, and influenced by a lot of factors (Southerland & Isherwood, 2016). Poncelas and Murphy (2007) found no statistically significant difference between the text comprehension of a political manifest which consisted of text and symbols, on the one hand, and the same political manifest with text only, on the other hand. Thirty-four adults with special needs participated in their study. They came to the conclusion that the meaning of pictorial symbols needs to be learned beforehand. Zentel (2010) also found no statistically significant advantage of adding symbols to texts. In contrast, Jones, Long, and Finlay (2007) proved that the reading comprehension of adults with special needs increases if symbols are added. According to them, especially participants with a low reading ability benefit from the addition of symbols. A qualitative study conducted by Scholz, Dönges, Risch, & Roth (2016) also supports the efficacy of symbols.

Generally, it can be stated that the samples of all of these studies were extremely small and, in addition, the participants were adults in all three studies (Poncelas & Murphy, 2007; Jones et al., 2007; Zentel, 2010). Furthermore, the studies focused only on the effectiveness of symbols and only marginally covered the question of how symbols are perceived. To understand how symbols are perceived by students with and without learning difficulties, we need to acquire an insight into the cognitive processing of symbols. This leads to the research questions of this project:

1. How do students with and without special needs rate symbols in learning material (e.g., concerning their helpfulness and fit)?
2. How do students with and without special needs perceive symbols used in learning materials (e.g., with regard to their influence on the reading process)?
3. Are students with and without special needs able to access symbols without a prior explanation?

Research Question 3 is clearly part of Research Questions 1 and 2. The reason for formulating a third research question about this specific aspect was to emphasize the fact that no introduction about how to use symbols is given. As we wanted to find out whether a prior explanation of the function and use of symbols is needed, we decided to formulate a third specific research question concerning this aspect.

## Method

### Participants

The participants of this study were students with and without special needs resulting from a learning disability. The term learning disability in Germany refers to an impairment of performance and learning behavior, especially with regard to school-based learning. Learning disabilities are often accompanied by impairments in motoric, sensory, cognitive, linguistic as well as social and emotional abilities (KMK, 1999).

Twelve students with and without special needs (learning disability) from grades 5, 6, and 7 participated in this interview study (N = 12; $M_{age}$ = 11.08; age range: 10-13 years; 50% female; cf. table 1). Additionally, the eye movements of four of these students (N = 4; $M_{age}$ = 11.75; age range: 11-13; 75% female) were recorded while working on the exercises (Table 1).

**Table 1. Participants**

| | Age | Grade | Sex | Special educational needs (SEN) | School form | Eye movements recorded |
|---|---|---|---|---|---|---|
| Student 1 | 12 | 5 | Female | Without SEN | Secondary school | Yes |
| Student 2 | 11 | 5 | Female | Without SEN | Inclusive School | Yes |
| Student 3 | 11 | 6 | Female | With SEN | Special school | No |
| Student 4 | 13 | 6 | Male | With SEN | Special school | Yes |
| Student 5 | 11 | 5 | Female | With SEN | Inclusive school | No |
| Student 6 | 10 | 5 | Male | Without SEN | Secondary school | No |
| Student 7 | 11 | 5 | Female | With SEN | Inclusive school | Yes |
| Student 8 | 10 | 5 | Male | Without SEN | Inclusive school | No |
| Student 9 | 12 | 7 | Male | With SEN | Special school | No |
| Student 10 | 10 | 5 | Male | Without SEN | Secondary school | No |
| Student 11 | 11 | 5 | Male | Without SEN | Inclusive School | No |
| Student 12 | 11 | 6 | Female | With SEN | Special School | No |

## Material

All students worked on tasks had the objective of introducing fractions in an activity-oriented manner with hands-on material. The written information utilized easy-to-read language augmented with pictorial symbols. The topic of fractions had not been covered in the students' mathematics classes beforehand. The subject was chosen because it had been intensively analyzed in German scientific literature (cf. Eichelmann, Narciss, Schnaubert, & Melis, 2012; Hefendehl-Hebeker, 1996; Malle, 2004; Pitkethly & Hunting, 1996; Padberg & Wartha, 2017; Schink, 2013; Winter, 1999). Thus, a sound theory-based introduction to fractions could be designed. Furthermore, fractions are considered to be a complex topic. The pupils need to develop new rational number concepts, as fractions differ from natural numbers in many aspects (Prediger, 2004; Siegler, Fazio, Bailey, & Zhou, 2013). Another reason for fractions' complexity is their multifaceted construct (Kieren, 1976).

After a first task complex, which aimed at familiarization with the material (Figure 2), the pupils received input about fractions by watching a video. This was followed by naming, marking, and sequencing fractions (Figure 3). To avoid spilt attention (Mayer, 2009), the symbols were always presented in close spatial proximity to the text (above the related words). We assumed that transparent and translucent symbols would best foster understanding, as they are easier to recognize than abstract symbols. Therefore, only these kinds of symbols were added to the keywords of the assignments. A pilot study was conducted to test the comprehensibility of these symbols. The participating students translated the symbols' meaning. They developed the symbols' meaning in the context of reasonable sentences. Fourteen of the 30 symbols were identified correctly by more than 80% of the students. Ten symbols were recognized by between 50% and 70% of the students, and only six of the 30 used symbols were recognized by fewer than 50% of the students. These six were adapted for the study. The symbols used in this study belong to the Metacom 7 symbol set (Kitzinger, 2015). As symbols for mathematical contents are rare, some symbols were developed by the authors.

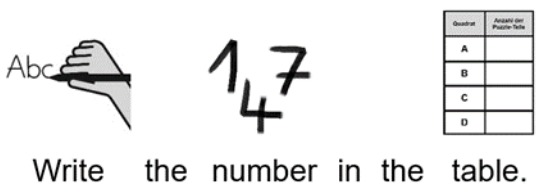



**Figure 2. Example Task Complex 1**

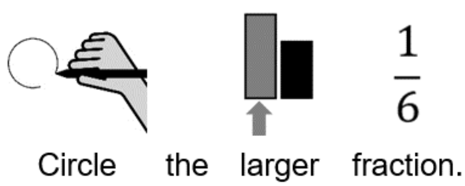



**Figure 3. Example Task Complex 2**

**Data Source**

After working on the tasks, all students participated in a structured interview. The interview dealt with the use of symbols (e.g., symbols' helpfulness and fit), the use of easy-to-read language (e.g., comprehensibility) as well as with the difficulty and the length of the exercises. The mean length of the individual interviews was approximately 18 minutes, with a range from 12 to 25 minutes. Each interview was video-taped and transcribed.

The tasks for the eye-tracking group were presented on a 22-inch screen with a 1366 × 768 pixels resolution using the hardware *The Eye Tribe Tracker PRO* and the software *EyeProof Recording Studio*. Every task was presented on a single page on the screen. While reading, the students sat at a distance of approximately 50 cm from the screen. The system was calibrated using an animated 9-point calibration image before every task. If the accuracy of the calibration was above 2 degrees of the visual angle, a new calibration automatically started. The mean accuracy of calibration was 0.35 degrees of the visual angle. The dynamic scanpath videos of every exercise of the four students (N = 67) made up the core data base of the eye-tracking analysis.

In addition to the interview and the eye tracking, the participants' general cognitive ability was assessed using part one (Subtest 1 to 4) of the CFT 20-R (Weiß & Weiß, 2006), which focuses on general fluid ability according to Cattell (1968). The participants' basal reading ability was captured using the German reading comprehension test SLS 2-9 (Wimmer & Mayringer, 2014) which emphasizes the comprehension of single sentence instead of complete text understanding.

## Procedure

To avoid excessive demands on the participants, data collection was divided into two sessions. During the first session, paper-and-pencil versions of both tests (CFT 20-R and SLS 2-9) were implemented. During the second session the participants worked on the tasks individually, and the interview was conducted afterwards. For the four students who participated in the eye tracking, the second session also included the students' familiarization with the eye-tracking system, the procedure of calibration, and a short example exercise. This took approximately three minutes. To ensure the comparability of results, the content of the example exercise had nothing to do with fractions. The students in the eye-tracking condition, read the 17 tasks on screen. After reading each task on screen, the students received related hands-on materials and worked on the task with paper and pencil.

## Data Analysis

The interview transcripts were evaluated using MAXQDA 11. To build categories, cycle methods (Saldana, 2009) orientated on the interview's structure were first used. A first coding cycle was followed by a second one. While the first cycle included elemental (structural as well as descriptive coding) and affective (evaluation coding) methods, the second cycle focused on coding patterns (ibid.). For example, in the first cycle, the category "symbols' helpfulness" consisted of the following codes:

1. Symbols are perceived as helpful.
2. Symbols are neither perceived as helpful nor as distracting.
3. Some symbols are perceived as helpful, some as distracting.
4. It is unclear whether the symbols are perceived as helpful or distracting.

These codes were formed deductively as well as inductively. In the second cycle these codes were identified as being of major importance for the study and were densified to form three levels of helpfulness. Furthermore, the answers that were assigned to Code 4 were analyzed again by referring back to the videos. The three levels of helpfulness formed the basis for the typology we developed (see Table 3).

The transcripts were coded by two raters and a Cohen's kappa (cf. Wirtz & Casper, 2002) of .75 was achieved in the first instance. Afterwards, not coincidently rated statements were discussed until the two raters came to an agreement. These communicatively validated results (cf. Kvale, 2007) are presented in the following chapter.

The calculation and visualization of the eye movements in scanpaths was based on a dispersion-based algorithm. This means that the dispersion (e.g., the spread distance) of fixation points in the eye-tracking protocols was emphasized by this algorithm. Furthermore, a dispersion-based algorithm uses duration information and is locally adaptive (Salvucci & Goldberg, 2000).

The development of the coding system was also based on techniques described by Saldana (2009). Most codes and categories were developed deductively; some were added inductively during the coding process. Every scanpath was coded and analyzed separately following the chronology of the reading process. This included reading the text as well as seeing the symbols. Two categories were differentiated in the coding process: the word and the sentence level. Each sentence was coded on both levels. The sentence level refers to the holistic observation of the task. This means that the student read every word of the assignment in one go without stopping. The student looked at the symbols (1) afterwards, (2) before, (3) afterwards and before, or (4) not at all. Each scanpath was coded according to when and whether the symbols were looked at using the following codes:

1. *Text-Symbols* (symbols were looked at after reading the assignment)
2. *Symbols- Text* (symbols were looked at before reading the assignment)
3. *Both* (symbols were looked at before and after reading the assignment)
4. *Text* (symbols were not looked at)

Figure 4 illustrates a scanpath screenshot, which was coded as *Text-Symbols* as the symbols were considered after reading only.

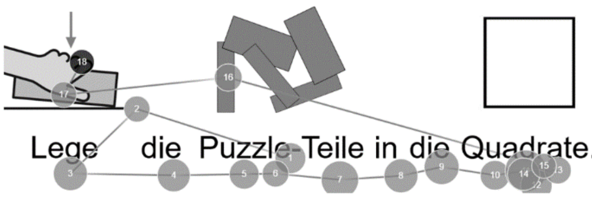
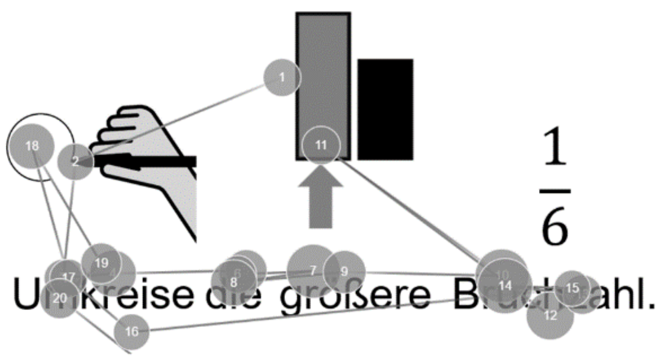



**Figure 4. Scanpath coded as Text-Symbols**

In addition to the sentence level, each scanpath was coded at the word level. Besides the holistic observation of the assignments, participants looked at single words and the corresponding pictures. Figure 5 shows a scanpath screenshot which was coded as *both* at the sentence level, as the symbols were viewed before and after reading. Additionally, the scanpath was coded as *transition* at the word level, because of the transition between the first word circle (German: umkreise) and the corresponding symbol.



Again, two raters coded the scanpaths and a Cohen's kappa (cf. Wirtz & Casper, 2002) of .73 was achieved in the first instance. As described earlier, non-concordant codes were discussed until the two raters reached an agreement.

## Results
### Interview

In the second coding cycle, the symbols' helpfulness and fit crystallized as major themes. These two categories were divided into three subcategories each. Table 2 provides an example of each code.

**Table 2. Overview of the students' answers for each field of the typology**

Helpfulness

| High | |
|---|---|
| Student 7: | They [the little pictures] helped me; they did not disturb me at all. |
| Interviewer: | And why did they help you? |
| Student 7: | You don’t have to understand everything by reading. You also see the things you have to do. |

| Middle | |
|---|---|
| Interviewer: | Did the little pictures help or did they disturb you? |
| Student 11: | Well, actually, in between usually. So, disturbed is completely wrong in my case, but sometimes I didn’t look at the pictures, because usually I didn’t need them at all. But, other people are probably helped a lot by the pictures. |

| Low | |
|---|---|
| No student was assigned to this category. The following answer was expected for this category: | |
| Student x: | The pictures did not help me. |

Fit of the symbols

| High (All symbols represent the words below) | |
|---|---|
| Student 9: | Are there any pictures that do not fit? |
| Interviewer: | (Student browses through all exercises) Actually not, all of them fit…yes, all of them fit. |

| Middle (Part of the symbols represent the words below) | |
|---|---|
| Interviewer: | Are there any pictures that do not fit? |
| Student 10: | (Student shakes his head) Not really. |
| Interviewer: | Not really? Would you like to check if there are any symbols that do not fit? |
| Student 10: | (Students looks at Exercise 1 and points at the symbol for *writing.*) There, for example, the hand with the letters. (Student says something that is not comprehensible.) |
| Interviewer: | Did this one fit or not? |
| Student 10: | Not really. |
| Interviewer: | Mhm, this one did not fit. Let’s go through the exercises; then you can look at them [the symbols] again (Interviewer browses through part of the exercises). |
| Student 10: | That’s it. |
| Interviewer: | That’s it? (Interviewer continues to browse through the exercises) Anything else? |
| Student 10: | Ehehm. |


*Symbol for writing*

| Low (Most of the symbols do not represent the words) | |
|---|---|
| No student was assigned to this category. The following answer was expected for this category: | |
| Student x: | Almost all pictures did not fit with the words. |

On the basis of this second cycle, a typology illustrating the students’ attitudes towards symbols was developed. This nine-field scheme includes the students’ attitude to the symbols’ helpfulness as well as their view of the symbols’ fit to the words they represent. The students were integrated into the scheme based on their statements in the interview (Table 3). The abbreviation SEN refers to students with special education needs.

**Table 3. Typology**

| | Fit of the symbols | | |
|---|---|---|---|
| | High | Middle | Low |

| | | | |
|---|---|---|---|
| Helpfulness of the symbols | High | Student1<br>Student 2<br>Student 3 (SEN)<br>Student 4 (SEN)<br>Student 6<br>Student 7 (SEN)<br>Student 9 | Student 10<br>Student 12 (SEN) |
| | Middle | Student 11 | Student 5 (SEN)<br>Student 8 |
| | Low | | |

Another important result of the interview was that almost all students were able to explain why there were symbols above the words (10 of the 12 students). The statements referring to this topic were categorized, as illustrated in Table 4.

**Table 4. Overview of the students' answers about symbols' function.**

| Symbols support the general comprehension of the text | |
|---|---|
| Student 7: | You don't have to understand everything by reading. You also see the things you have to do. |

| Symbols are used to recheck meaning | |
|---|---|
| Student 2: | Hm, first I read and then I looked at the pictures to find out whether I understood it correctly. |
| Interviewer: | Mhm. |
| Student 2: | And if not, then, I read it again and looked at the pictures. |

| Symbols help if comprehension problems arise | |
|---|---|
| Student 2: | Ehm, the little pictures helped me because I could see how it works. |
| Interviewer: | Mhm. |
| Student 2: | Because sometimes I didn't understand the text and then I looked at the pictures and they helped me. |
| Interviewer: | Good. |
| Student 2: | Because, if you don't understand it completely, then you can see how you are supposed to do it there. |

| Symbols help for understanding individual words (student uses one or more examples to illustrate the symbols' function) | | |
|---|---|---|
| Student 6: | Yes, eh, because there, because then, because there (Student 6 points at the symbol laptop, which looks like a laptop, and reads aloud the corresponding assignment) "Watch the video". There was also a laptop, so (Student 6 points at the real laptop) a laptop and yes. |  *Symbol for laptop* |
| Interviewer: | Mhm. | |

| | | |
|---|---|---|
| Student 6: | And, ehm (Student 6 points at the symbols headphone), there the headphones, because this (Student 6 reads aloud the corresponding assignment) "put the headphones on" and then you know it better, well…yes. |  *Symbol for headphone* |

| Not clear whether student recognizes the symbols' function | |
|---|---|
| Interviewer: | What do you think: Why are there symbols above the words? |
| Student 12: | Hm, I don't know. To look at them exactly. |
| Interviewer: | Mhm. Anything else? |
| Student 12: | No. |

Before discussing the functions mentioned in more detail, we want to zoom in on the upper-left rectangle of the typology (Table 3). The next paragraphs focus on the eye-tracking data of four students (Student 1, Student 2, Student 4, and Student 7) who described the symbols as fitting and helpful.

## Eye Tracking

The analysis of the scanpaths of these four students shows that symbols influence the reading process of the assignments because they almost always looked at the symbols before, after, or before and after. They refrained from looking at them in only very few cases; no pattern could be found concerning which symbols were ignored.

Students rarely moved their eyes between single words and their corresponding picture. This means that no complete sentences were viewed following the pattern of moving from word to symbol and back to the word again. With a few exceptions, the students read the sentences in one go without stopping. Only single words and the corresponding symbols were looked at following the transition pattern. Table 5 summarizes the number of observation patterns for each individual student and for all students. It also includes information on the students' educational needs, reading ability, and cognitive ability.

**Table 5. Overview of the number of students' observation patterns, their educational needs, reading ability, and cognitive ability**

| | Student 1 | Student 2 | Student 4 | Student 7 | All students |
|---|---|---|---|---|---|
| Sentence Level | | | | | |
| Both | 10 | 8 | 11 | 9 | 38 |
| Text-Symbols | 2 | 4 | 4 | 2 | 12 |
| Symbols-Text | 2 | 2 | 1 | 2 | 7 |
| Text | 3 | 3 | 0 | 4 | 10 |
| Word level | | | | | |
| Transition (Words where transitions were observed) | 8 (write, video, area [two times], square D, all squares, begin, fraction) | 5 (count, fraction [two times], square D, all squares) | 7 (puzzle pieces, count, write, fraction, take, order, write) | 8 (count [two times], circle, take, all squares, puzzle pieces, order, begin) | 28 |
| Special educational needs (SEN) | | | | | |
| | without SEN | without SEN | with SEN | with SEN | |
| Reading ability (M = 100; SD = 15) | | | | | |
| | 78 | 86 | 66 | 70 | |

| | | | | |
|---|---|---|---|---|
| Cognitive ability (M = 100; SD = 15) | | | | |
| | 94 | 100 | 104 | 76 |
| Age | | | | |
| | 12 | 12 | 13 | 11 |
| Grade | | | | |
| | 5 | 5 | 6 | 5 |

*Note:* In the case of Student 4, one scanpath was not recorded due to technical problems.

## Discussion

This study aimed at investigating how symbols are perceived by students with and without special needs. With the help of interviews and recording of the students' eye movements while they were working on the exercises, we wanted to acquire an insight into the cognitive processes underlying the perception of symbols. In this chapter, the study's main results will be summarized and brought together with reference to the three main research questions. The first research question was: How do students with and without special needs rate symbols in learning material (e.g., with regard to their helpfulness and fit)?

The typology, which is based on the students' statements during the interview, shows that students with and without special needs are similarly distributed in the different fields. Thus, the students' attitudes towards symbols seem to be independent of their learning condition. Furthermore, all of the students classified the fit and helpfulness of the symbols at least as medium. Thus, the students' general attitude towards symbols can be described as positive.

Regarding Research Question 2 (How do students with and without special needs perceive symbols in learning material?), the result was similar: On the basis of the scanpaths, no different types of viewers were found. All students looked at the symbols in individually different and flexible ways. No individual preferences were found. Thus, the students' reading and cognitive ability as well as their special educational needs did not seem to influence the order or pattern with which the text and the symbols were viewed. A reason for the similarity in pattern across the students could be that all students, students with and without SEN, benefit from the availability of symbols.

Both the interview and the eye tracking show that the students' general attitude towards (Research Question 1) and perception of (Research Question 2) symbols seems to be independent of their learning conditions. Students with and without special needs were similarly distributed in the fields (cf. Table 3) and, on the basis of the scanpaths, no different types of viewers were found, as all students used all patterns in flexible ways (cf. Table 4). Furthermore, the students' general attitude towards the symbols can be described as rather positive (cf. Table 3).

Another important aspect of Research Question 2 concerns the symbols' influence on the reading process. As already illustrated, the symbols were primarily used to acquire a holistic understanding of the assignment. The sentences were mainly read in one go, and no complete sentence was viewed with the *transition* pattern. Students did not read a sentence word by word and look at each corresponding symbol. Such a pattern was not found in any of the 67 scanpaths. Only single words and their relevant symbols were looked at in this manner. Thus, the symbols were mainly utilized to achieve a holistic comprehension of the assignments (sentence level) and not used to support the understanding of single words (word level).

As the support provided by symbols for the comprehension of complete sentences seems to be stronger than facilitating the understanding of single words, the following educational implication may be derived. One or few symbols illustrating the content of a whole sentence could be beneficial, instead of symbols representing single words. Thus, the development of symbols that visualize the content of complete sentences might be beneficial. As the development of such symbols is rather time-consuming and complex, the use of photos representing the sentential logic could be an alternative, because they are easier to produce. This conclusion conforms with earlier studies (Mirenda & Locke,1989, Sevcik & Romski, 1986). Even though it can be assumed that photographs require a minimal amount of cognitive processing (Mirenda, 1985), it must be taken into account that photos, like symbols, can be misinterpreted (Ward & Townsley, 2005). Furthermore, when using photos or symbols that represent the content of whole sentence, transitions between single words and their relevant symbols are impossible. The reading process of some students may be hindered by this restriction. Thus, further studies are needed to investigate the use of photos and symbols that represent the content of whole sentences.

The third research question was: Are students with and without special needs able to access symbols without a prior explanation? If we consider the eye-tracking data, the code *text*, which means that the symbols are not looked at, rarely occurs. Only 10 of the 67scanpaths were coded as *text* (see also Table 5). Even though the purpose of the symbols above the words was not explained to the students, the students looked at them intuitively. Thus, based on the eye-tracking data, a positive answer can be given to Research Question 3.

During the interview, the students were asked why they thought there were pictures above the words. Almost all students could explain this; and four main functions were derived from the students' answers:

- Symbols support the general comprehension of the text
- Symbols are used to recheck meaning
- Symbols help if comprehension problems arise
- Symbols help for understanding individual words (student uses one or more examples to illustrate the symbols' function)

Some students mention more than one of these functions, which shows that they are able to use the symbols in a flexible way depending on their needs (to recheck, to overcome comprehension problems, to achieve an overall understanding of the assignment, etc.). Thus, no prior explanation about the function of symbols seems to be needed.

If we bring together the students' statements in the interview with their corresponding eye-tracking data, another aspect becomes apparent. If a student did not mention a certain aspect, it did not mean that he or she was not implicitly aware of it. For example, Student 4 was not able to mention any of the established functions (cf. Table 4). Nevertheless, his eye-tracking data shows that he looked at the symbols in a differentiated way. This leads to the assumption that, even though Student 4 did not articulate the purpose of the symbols properly, he was able to use them efficiently. Students 7, 2, and 1 mentioned only one symbol function each. However, their eye-tracking data shows that they actually used the symbols in different manners (to recheck complete sentences, to understand individual words, etc.). Thus, it can be assumed that, even though they mentioned only one function, they were implicitly aware of the others.

However, the small number of students limits the generalizability of our results and conclusions. Only 12 students took part in the interview, and only four of them participated in the eye tracking. A total of only 67 scanpaths was analyzed. Larger studies are needed to replicate the study's results. Furthermore, the methodological pitfalls should not be neglected. For example, we need to bear in mind the effect of social desirability and acquiescence on interviews (cf. Bryman, 2012), and the eye-tracking data can only serve as a valid indicator for perception if we apply the *eye-mind* and *immediacy assumption* (Just & Carpenter, 1980). Both assume that observed symbols are cognitively processed immediately. Furthermore, by editing the data (e.g., the transcription of the interviews), the raw data were changed. In this study, we aimed at referring to the primary data, for example, by using the interview videos during the process of coding. Thus, the coding scheme was not based on the transcripts only. Another limitation is that no conclusion concerning the influence of symbols on the correctness of results can be drawn based on our data. Larger quantitative studies are needed to analyze whether symbols and/or photographs influence the performance of students in mathematics and other subjects. Despite these limitations, the study's aim to acquire a first qualitative insight into the processing of symbols from different perspectives was achieved.

One student summarized her eye movements as follows: "I looked at the pictures. Well, first I read the text, then I looked at the pictures, and then knew what I had to do". This statement represents the overall findings of this study quite well: The symbols have an influence, but do not interrupt the flow of reading; they are looked at before and/or after reading the text. Furthermore, students have a rather positive attitude towards symbols.

## References:


Bryman, A. (2012). *Social research methods* (4th ed.). Oxford: Oxford University Press.

Cattell, R. B. (1968*)*. Are IQ Test intelligent? *Psychology today*, 16.

Detheridge, T., & Detheridge, M. (2002). *Literacy through Symbols: Improving Access for Children and Adults* (2nd ed.). London: David Fulton.

Erickson, K. A., & Geist, L. A. (2016). The profiles of students with significant cognitive disabilities and complex communication needs. *Augmentative and Alternative Communication*, 32(3), 187–97. doi:10.1080/07434618.2016.1213312

Eichelmann, A., Narciss, S., Schnaubert, L., & Melis, E. (2012). Typische Fehler bei der Addition und Subtraktion von Brüchen [Typical errors for fraction addition and subtraction.]. *Journal für Mathematik-Didaktik*, 33, 29-57. doi:10.1007/s13138-011-0031-5

Hefendehl-Hebeker, L. (1996). Brüche haben viele Gesichter [Fractions possess many faces]. *Mathematik lehren*, 78, 20-48.

Hurtado, B., Jones, L., & Burniston, F. (2014). Is easy read information really easier to read*? Journal of Intellectual Disability Research,* 58, 822-829. doi: 10.1111/jir.12097

Just, M.& Carpenter, P. A. (1976). Eye fixations and cognitive processes. *Cognitive Psychology*, 8, 441–480.

Kieren, T.E. (1976). On the mathematical, cognitive, and instructional foundations of rational numbers. In R. Lesh (Ed.), *Number and Measurement: Papers from a Research Workshop* (101-144). Columbus, Ohio: ERIC/SMEAC

Kitzinger, A. (2015). METACOM 7. *Symbolsystem zur Unterstützten Kommunikation*. [Symbol set for Augmentative and Alternative Communication]. Oeversee.

Kvale, S. (2007). *Doing Interviews*. London: Sage.

Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (1999). [Recommendations concerning learning disabilities.]. Retrieved from http://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2000/sopale.pdf

Langer, I., Schulz von Thun, F.S., & Tausch, R. (2011). *Sich verständlich ausdrücken* [Express yourself in an understandable way]. München: Ernst Reinhardt Verlag.

Malle, G. (2004). Grundvorstellungen zu Bruchzahlen [Basic ideas about fractions]. *Mathematik lehren,* 123, 4-8.

Mayer, R. (2009). *Multimedia Learning* (2nd ed.). Cambridge: Cambridge University Press.

Mirenda, P. (1985). Designing pictorial communication systems for physically able-bodied students with severe handicaps. *Augmentative and Alternative Communication*, 1:2, 58–64. doi:10.1080/07434618512331273541

Mirenda, P., & Locke, P.A. (1989). A comparison of symbol transparency in nonspeaking persons with intellectual disabilities. *Journal of Speech and Hearing Disorders*, 54 (2), 131-140. doi:10.1044/jshd.5402.131

Netzwerk leichte Sprache [Network easy-to-read language] (2006). Regeln für die leichte Sprache [Easy-to-read guidelines]. Retrieved from: http://www.leichtesprache.org/images/Regeln_Leichte_Sprache.pdf

Padberg, F. & Wartha, S. (2017). *Didaktik der Bruchrechnung* [Didactics of fractions] (5th ed.). Heidelberg: Spektrum Akademischer Verlag.

Pitkethly, A. & Hunting, R. (1996). A review of recent research in the area of initial fraction concepts. *Educational Studies in Mathematics*, 30 (1), 5-38.

Prediger, S. (2004). Brüche bei den Brüchen [Breaks of fractions]. *Mathematik lehren*, 123, 10-13.

Poncelas, A., & Murphy, G. (2007). Accessible Information for People with Intellectual Disabilities. Do Symbols Really Help? *Journal of Applied Research in Intellectual Disabilities,* 20(5), 466-474.

Saldana, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). Los Angeles: Sage.

Schink, A. (2013). *Flexibler Umgang mit Brüchen.* [Flexible handling of fractions.] Wiesbaden: Springer Fachmedien Wiesbaden.

Schnotz, W. (2005). An Integrated Model of Text and Picture Comprehension. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning.* (49-70). Cambridge: Cambridge University Press.

Scholz, M., Dönges, C., Dechant, C. & Endres, A. (2016). Theoretische und konzeptionelle Überlegungen zur Vermeidung von Lesebarrieren bei naturwissenschaftlichen Schülerexperimenten. [Theoretical and conceptual approaches to reduce reading barriers in natural scientific texts.] *Zeitschrift für Heilpädagogik*, 67(10), 454-464.

Scholz, M., Dönges, C., Risch, B. & Roth, J. (2016). Anpassung von Arbeitsmaterialien für selbstständiges Arbeiten von Schülerinnen und Schülern mit kognitiven Beeinträchtigungen in Schülerlaboren. [Modification of learning material for pupils with intellectual disabilities in off campus student laboratories.] *Zeitschrift für Heilpädagogik*, 67(7), 318-328.

Scholz, M., Wagner, M., & Negwer, M. (2016). Motorische Fähigkeiten und Kompetenzen im Bereich Kulturtechniken von Schülerinnen und Schülern an Schulen mit dem Förderschwerpunkt körperliche und motorische Entwicklung. [Motor skills and competences in cultural techniques of students with special educational needs.] *Heilpädagogische Forschung*, 42(4), 191–201.

Sevcik, R., & Romski, M. A. (1986). Representational matching skills of persons with severe retardation. *Augmentative and Alternative Communication*, 2, 160–164. doi:10.1080/07434618612331273980

Siegler, R. S., Fazio, L. K., Bailey, D. H. & Zhou, X. (2013). Fractions: the new frontier for theories of numerical development. *Trends in Cognitive Sciences,* 17(1), 13-19.

Southerland, R. J., & Isherwood, T. (2016). The Evidence for Easy-Read for People with Intellectual Disabilities: A Systematic Literature Review. *Journal of Policy and Practice in Intellectual Disabilities*, 13(4), 297-310. doi:10.1111/jppi.12201

Ward, L., & Townsley, R. (2005). 'It's about a dialogue. . .' Working with people with learning difficulties to develop accessible information. *British Journal of Learning Disabilities*, 33, 59–64.

Weiß, R. H., & Weiß, B. (2006). *CFT 20-R: Grundintelligenztest Skala 2, Revision*. [CFT 20-R: Basic cognition scale 2]. Göttingen: Hogrefe.

Wimmer, H., & Mayringer, H. (2014). *SLS 2-9: Salzburger Lese-Screening für die Schulstufen 2-9.* [SLS 2-9: Salzburg Reading-Screening from grade 2 to 9]. Bern: Hogrefe.

Winter, H. (1999). *Mehr Sinnstiftung, mehr Einsicht, mehr Leistungsfähigkeit, dargestellt am Beispiel der Bruchrechnung* [More meaningfulness, more insight, more performance exemplified by fractions]. Retrieved from http://blk.mat.unibayreuth.de/material/db/37/bruchrechnung.pdf

Wirtz, M., & Casper, C. (2002). *Beurteilerübereinstimmung und Beurteilerreliabilität*. [Accordance and reliability between raters.] Göttingen: Hogrefe-Verlag.

Zentel, P. (2010). *Zur Bedeutung von multiplen Repräsentationen beim Lernen mit Computer und Internet für Menschen mit geistiger Behinderung* [The significance of multiple representations for learning with computers and internet for people with intellectual disabilities] (Doctoral dissertation, Eberhard-Karls-University Tübingen, Germany). Retrieved from https://publikationen.uni-tuebingen.de/xmlui/handle/10900/47815