Towards gesture-based literacy training with a virtual agent

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Abstract

Illiteracy remains a persistent problem all over the world. Especially people with cognitive impairments are affected and, at the same time, often excluded from interventions because courses and e-learning materials are not tailored to the particular needs of these people. A teaching method that is occasionally applied in special schools is a gesture-based training: Learning of letter-sound pairs is supported by associated gestures. In this paper first steps towards realizing this methodology with a *virtual* teacher are presented. We apply a user-centered approach and present a first prototype system which is used to set up an evaluation with learners from the target audience. In the study, participants learned with the system in consecutive learning sessions over three days. We present results with regard to the general acceptability of the system, problems the learners had as well as issues of the system they liked. The outcome of the study serves to inform future versions of the prototype system.

1 Introduction

Illiteracy is a serious problem given that reading and writing are basic skills in our contemporary information society. According to the United Nations, 15.9% of the world population is illiterate[1]. In the European Union, illiteracy in the strict sense that people are not able to read and write a single word, is nearly eradicated. However, the phenomenon of *functional illiteracy* in adults is becoming increasingly serious, i.e., people can read or write single words and short sentences, but no longer sentences or continuous text. One in five young people in Europe has such poor reading and writing skills[2]. Insufficient literacy has severe consequences. People with low literacy are less likely to finish school, more likely to be unemployed, especially in times of crisis, and more likely to suffer from poor health. Although various intervention programs have been set up over the past decade (2003-2012 was the United Nations Literacy Decade), very little progress has been made in terms decreasing illiteracy rates, so far. In other words, there is an urgent need for effective literacy programs.

One group that is particularly affected by illiteracy are people with learning difficulties or cognitive impairments. For these people, the situation is further hampered because courses and training materials are not tailored with regard to their special needs. They are typically reliant on individual tutoring which is expensive and rarely available–even in specialized schools. This target group is, at the same time, very interesting to develop courses or other kinds of literacy training materials with. The outcome of projects developing for and with handicapped people are typically systems which are particularly easy to use and can, hence, also be used easily by others (contrary to the other way around).

An interesting approach to overcome illiteracy has been described in the literature for a long time: gesture-based literacy training (Koch, 1939; Kossow, 1979; Bleidick and Kraft, 1966; Radigk, 1975). Basically the idea is to support letter-sound integration by gestures. That is, students learn to associate

[1] UNESCO Institute for Statistics, September 2012
[2] Programme for International Student Assessment (PISA), 2009

K. Jokinen and M. Vels. 2015. Proceedings of The 2nd European and the 5th Nordic Symposium on Multimodal Communication.

not only a particular letter with a sound, but also a related gesture. The methodology has found its way especially into schools specialized for handicapped students. There is, however, no standard system available and every teacher employs the methodology with her own gesture repertoire. So pupils are running into problems when they have to change classes or schools. Likewise, adult learners are struggling when hey change courses or when their course it taught by a different teacher for any reason.

At the same time, research on pedagogical agents is providing virtual characters to be applied in the role of teachers, tutors or trainers (Heidig and Clarebout, 2011). These characters can train learners with flexible and customized multimodal materials, and can motivate them through supportive feedback (Baylor and Kim, 2009). Research with virtual agents engaged as trainers in learning tasks has actually shown that gesture-supported learning can increase memory performance for vocabularies (Bergmann and Macedonia, 2013). Moreover, with regard to acceptance, previous research has shown that people with cognitive impairments show a high degree of acceptance and desirability of personal virtual assistants for daily use (Yaghoubzadeh et al., 2013; Kramer et al., 2013).

In this paper, we aim to integrate these two directions in a gesture-supported literacy training with a virtual human for people with cognitive impairments. Applying a virtual character as a teacher in the sensitive domain of literacy education for adults might be particularly advantageous as illiterate people often feel embarrassed when they have to admit their illiteracy to other people. This is one of the reasons why they do not attend courses or make demands on other kinds of instruction. To tailor the system to the particular needs of the target group, we apply a user-centered design approach (Abras et al., 2012). In this methodology, one builds prototypes already at an early stage and improves these prototypes iteratively on the basis of tests and evaluations with users. Within this methodological framework, we set up a prototype system for several short training sessions and evaluated this with participants from the target audience. In the evaluation we were particularly interested in the general feasibility of the approach, in participants' acceptance and appreciation, and potential problems or challenges from the participants' perspective. The remainder of the paper is structured as follows. In Sect. 2 we provide background information about gesture-based literary training. In Sect. 3 we present a first prototype system which allowed us to set up consecutive three training sessions. In Sect. 4 an evaluation study and first results thereof are reported. We conclude in Sect. 5 with a summary and discussion.

2 Gesture-based literacy training

Gesture-based systems to overcome illiteracy have their origin in very early work, for instance, by Ickelsamer (1530), Grosselin (1866) and Piper (1898) (cf. Schäfer (2011)). At the beginning of the 20th century, Franz-Joseph Koch proposed the 'Fingerlesemethode' (engl. 'finger reading method'; Koch (1939)) which spread the idea of becoming literate with gestures into schools. In Koch's approach speech sounds are associated with natural sounds from the environment or from everyday life and accompanied with related hand and arm movements. For instance, the IPA 'ʃ' is associated with clapping hands because the 'ʃ' occurs in the word 'to shoo' (German: 'scheuchen'). The gestures are performed in front of the face while performing the very sound.

Subsequently, others started to develop various gesture-based systems that were based on Koch's method. Kossow (1979), for instance, set up a gesture set consisting of different signs for vocals and consonants, respectively. Signs for vocals depict the mouth posture while the sound is being articulated. For consonants, the hands are brought into specific position and configurations close to the mouth such that the learner is enabled to sense the air stream, lip configuration and larynge movement. Overall, Koch's and Kossows systems are rather *fine-motoric*, characterized by particular handshapes and hand configurations.

By contrast, others have developed gesture sets which are rather gross-motoric. That is, the employed gestures are characterized by rather large movements of hands and arms. Bleidick & Kraft (1966), for instance, combined hand and arm gestures established in music education and eurythmy (a movement art developed at the beginning of the 19th century). In Bleidick & Kraft's approach the employed gestures fall into the two categories for vocals and consonants. Vocals are depicted statically depending on their pitch (e.g., 'e' is high, 'u' is low). Consonants are depicted dynamically. Another gross-motoric system

has been developed by Radigk (1975). Here, the selected gestures come from different domains. Some are taken from speech therapy, others bear some resemblance with the shape of letters, e.g., the gesture for 'T' is a T-shaped configuration of both arms.

These methods have been employed successfully in many schools in the 1970s and 1980s, but they were displaced over the years by more modern teaching methods. Only in special schools for handicapped children they have been kept to date. Here, gesture-based methods to become literate got integrated into the curricula because they are a major help for weak pupils in particular. Recently, the gesture-based literacy teaching is becoming more popular again. For instance, private schools in Germany ('Hasenschulen'[3]) are established where children who did not manage to become literate at their regular school are taught successfully with Koch's finger reading method.

It appears that especially the fine-motoric gesture sets (especially Koch's approach) found their way into usage. So the question might come up whether these have any advantages for the learners. To date (and to the best of the author's knowledge), there are no comparing studies of the two approaches. To explore this question, we will realize parts of both, fine- and gross-motoric approaches, in our prototype system. We can, hence, evaluate whether learners have particular problems with one system or the other, or whether they have preference for any of the two approaches.

3 Prototype System

We set up a prototype system to realize the basic idea of a virtual agent engaging in the role of a teacher for literacy education with cognitively impaired learners. The prototype employs the virtual character 'Billie' driven by the ASAP realizer system for multimodal behavior realization (van Welbergen et al., 2014). The agent's behavior is specified in the Behavior Markup Language (BML; Vilhjalmsson et al. (2007)). Speech is synthesized with the text-to-speech system MaryTTS employing a German voice (Schröder and Trouvain, 2003). The current prototype is implemented as a wizard-of-oz system. That is, instead of automatic perception components (speech recognition, gesture recognition etc.) a human wizard interprets the learners' verbal and nonverbal behavior and initiates the agent behavior. Basically, we set up four different kinds of teaching units: (i) Letter introduction units in which the agent introduces a new letter to the learner, (ii) Letter repetition units in which an already introduced letter was further trained in interaction between agent and learner, (iii) Joint reading units in which agent and learner read words (consisting of known letters) together, and (iv) Independent reading units in which the learner is encouraged to read words on her own. In the following we present the main features of these four units.

Introducing a letter. The letter to be learned is displayed on a blackboard behind the virtual character. The agent uses a pointing gesture to refer to the letter and names it for the learner. Subsequently the agent lists some example words in which the letter occurs (see Table 1). Next, the agent performs the gesture for the letter to be learned and encourages the learner to perform the same movement together with him. Before executing the gesture once again, the agent explains some peculiarities of the movement and then performs the gesture three more times together with the learner. Next, the learner is assigned to repeat the gestural movement another three times on her own while also performing the speech sound associated with the letter. Finally, the agent asks the learner whether she wants to repeat the letter once again and if the learner repeats with 'yes', another three repetitions of gesture and spoken sound are conducted.

Repetition of a letter. To repeat a particular sound-letter-gesture combination, the letter was again displayed on the blackboard. The agent encourages the learner to perform the very movement together with him. Then the virtual character performs the gesture to be imitated or performed simultaneously.

Joint reading of a word. The letters of the word to be read (consisting of known letters) are displayed on the blackboard. The virtual character performs the sequence of gestures and speech sound associated with the letters respectively. Subsequently, learners are encouraged to read words together with the agent by performing the gestures and speech sounds simultaneously.

[3] www.hasenschule.de

Independent reading of a word. The letters of the word to be read (consisting of known letters) are displayed on the blackboard. The agent invites the learner to try to read the words on her own. Whenever learners need help, they can request support by the virtual teacher who can either help out with the spoken sound of a letter and its accompanying gesture, or with the complete (spoken and gesticulated) word. For the case that no help was necessary, the agent just stands still. When the learner reads the word successfully, the virtual character provides positive feedback and compliments the learner. When the word is not read out correctly by the learner, the agent encourages the learner to try it once again.

4 Evaluation study and first results

In the evaluation study we tested the prototype system described above. Note that this evaluation is not a controlled study testing a readily implemented system. It is rather a first qualitative evaluation of a prototype within the scope of a user-centered design. That is, the results are to gain insights into general acceptability of the system, to identify potential problems the learners might have as well as favorable issues of the system. The outcome of the study serves to inform future versions of the prototype system.

Materials The prototype system was brought to application with content in terms of six letters: the three vowels 'A', 'E', and 'U' as well as the three consonants 'B', 'S', and 'T'. The gestures for these letters were realized in two ways: (1) in the gross-motoric approach by (Bleidick & Kraft, 1966) and (2) in the fine-motoric approach by Koch (1939). According to the latter, the 'S' is taught in two variants, namely voiced and voiceless. See Figure 1 for visualizations of the gestures as performed by the virtual agent. This distinction increases the number of letters being realized in the fine-motoric approach to seven. The gestures are taught together with particular approach-specific example words. Here we employed those words that have been which are provided by Koch (1939) and Bleidick & Kraft (1966) for their proposed gestures sets, respectively (see Table 1). For Koch's fine-motoric approach these example words were children's names and names for everyday objects. For Bleidick & Kraft's gross-motoric approach the words referred to the shape of the letters and gestures.

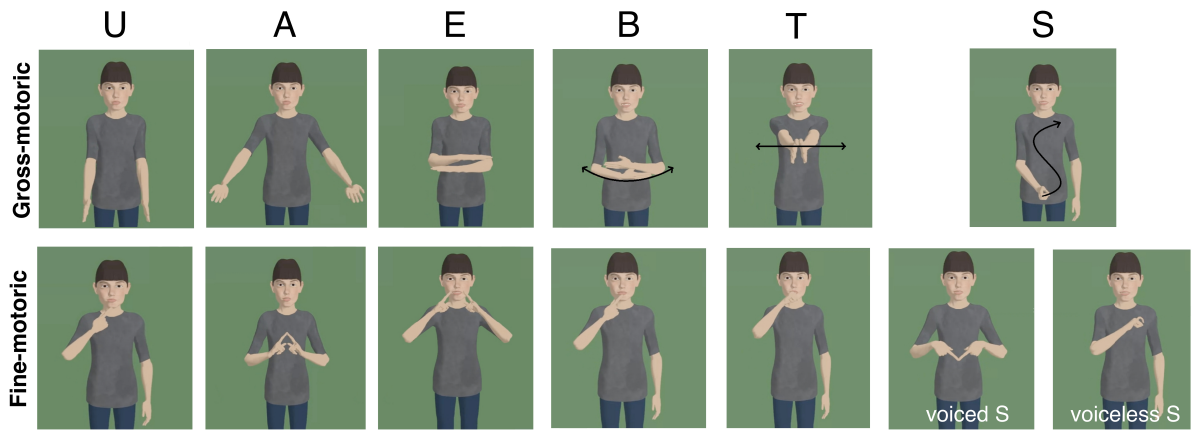

Figure 1: Gestures performed by the virtual agent for the letters taught in the evaluation study: Gross-motoric gestures (Bleidick & Kraft, 1966) in the upper row, fine-motric gestures (Koch,1939) in the bottom row.

Procedure The experimental procedure comprised three learning sessions taking place on three consecutive days. Upon arrival on day one, participants were informed about the course of the study by the experimenter. Next, they fulfilled a standardized pre-test to assess their literal skills[4] and were assigned for training either with the fine-motoric or the gross-motoric system. Subsequently, the first lesson started with a welcome by the virtual agent. The further course of the session follows the schedule as

[4]PROSON Kompetenzfeststellung Sprechen, Lesen und Schreiben (Engl.: PROSON Assessment of competence in speaking, reading and writing)

Table 1: Example words for the letters employed in the letter introductions. The fine-motoric system (Koch, 1939) employs names for everyday objects and children's names. The words in the gross-motoric system (Bleidick & Kraft, 1966) refer to the shape of the gesture for the very letter.

Letter	**Example words**	
	Fine-motoric approach (Koch, 1939)	**Gross-motoric approach** (Bleidick and Kraft, 1966)
A	Arm (Engl. 'arm')	Ankunft (Engl. 'arrival')
	Augen (Engl 'eyes')	Abend (Engl. 'evening')
	Anna	Abschied (Engl. 'farewell')
E	Elefant (Engl. 'elephant')	Wehe (Engl. 'woe')
	Emil	Gefahr (Engl. 'danger')
	Esel (Engl. 'donkey')	Erschrecken (Engl. 'frighning')
U	lustig (Engl. 'funny')	gruselig (Engl. 'creepy')
	Fuchs (Engl. 'fox')	unten (Engl. 'down')
	Schule (Engl. 'school')	dunkel (Engl. 'dark')
S		sofort (Engl. 'immediately')
		Stille (Engl. 'silence ')
		Pssst (Engl. 'Shhh')
S (voiceless)	Essen (Engl. 'food')	
	anders (Engl. 'different')	
	Horst	
S (voiced)	Summen (Engl. 'buzzing')	
	Senf (Engl. 'mustard')	
	Sardine (Engl. 'sardine')	
T	Tanz (Engl. 'dance')	Trommel (Engl. 'drum')
	Traum (Engl. 'dream')	Ton (Engl. 'tone')
	Tino	Tuba (Engl. 'tuba')
B	Baum (Engl. 'tree')	Bauch (Engl. 'belly')
	Ball (Engl. 'ball')	Bett (Engl. 'bed')
	Bernd	Baby (Engl. 'baby')

summarized in Table 2 consisting of several of the teaching units described in Sect 3. For instance, session 1 comprised of three introductory units for the vowels 'A', 'E' and 'U', respectively. Each session was completed with a post-session questionnaire which was read to the participants. Participants' oral answers were written down by the experimenter. Questions covered the following issues:

- Assessment of the gestures (e.g., clarity of the agents' gestures, difficulty of performing the gestures)
- Assessment of the agent's overall behavior (e.g., comments given by the agent)
- Overall assessment of the system (e.g., joy of interaction with 'Billie', joy of learning with body movements)

Participants Cognitively impaired participants were recruited from the clientele of an institution where people of all ages with various cognitive impairments can attend computer and photography courses (PIKSL lab[5]). Participants (n=5, 3 male, 2 female, aged 24 to 57) had different degrees of illiteracy. As measured with the PROSON literacy test (see above) two of them were illiterate (lowest level A01), and three of them were classified as literate (highest level A03). As we were mostly interested in acceptance and potential problems with the learning approach, we did not restrict participation to illiterate people.

Table 2: Course of the three training sessions taking place on three consecutive days.

Session 1	Introduction: 'A', 'E', 'U' Questionnaire
Session 2	Repetition: 'A', 'E', 'U' Introduction: 'B', 'S', 'T' Questionnaire
Session 3	Repetition: 'A', 'E', 'U', 'B', 'S', 'T' Joint reading: 'BUS', 'AST', 'TABU', 'UTE', 'ASS' Independent reading: 'BETT', 'TEST', 'SAAT', 'TUBA', 'TUBE' Questionnaire

Results First of all, all participants managed to interact with the system easily. All of them saw the sessions to the finish and no one quit her participation early, although the study stretched across several days.

One goal of the evaluation was to gain insights into problematic and challenging issues from the participants' perspective. It turned out that training with the gross-motoric system by Bleidick & Kraft (1966) resulted in problems with one out of six letters, namely the 'S'. All three participants who trained with the gross-motoric gestures had problems with this letter. They stated that the S-gesture was either difficult to recognize when performed by the virtual character, or hard to remember. This subjective impression of the participants is in line with observations from the interactions. No one of the three participants was immediately able to imitate the S-gesture correctly. All participants repeated the S-gesture more often than the other gestures in order to memorize it. The direction of movement (from bottom to top) seemed to be counterintuitive for the participants and was, in particular, hard to memorize. For one of the three participants, the difficulties in gesture performance and memorization had an impact on the feeling of joy during learning. This learner reported less fun while learning and repeating the letter 'S' as compared to the other five letters. The other two participants who also had problems with the S-gesture, nevertheless, reported a comparable degree of fun for all six gestures.

For participants training with the fine-motoric system by Koch (1939) the amount of problematic gestures/letters was higher as compared to the gross-motoric system. Both participants had problems with the vowel 'A'. They reported that the 'A' was particularly difficult and their gesture performance

[5]http://www.piksl.net

for the ‘A’ was not exact. One of the participants, moreover, reported that the gestures for the other two vowels ‘E’ and ‘U’ were hard to recognize because the gestures were performed directly in front of there agent’s face. In session 2, when the consonants were trained, both participants had problems with the letters ‘B’ and ‘U’ which were apparently too similar. These letters were mixed up by both participants. Another problem was the voiceless ‘S’. One participant reported problems to recognize this gesture, especially when it had to be distinguished from the voiced ‘S’ gesture. Both participants had obvious problems with the performance of the voiceless ‘S’ gesture such that the gesture was not performed correctly.

Another aspect to look at is participants’ independent reading ability in the end. Were the learners able to read the five selected words at the end of session 3? As expected, the three literate participants had no problems reading the words. Among the illiterate participants, the person who trained with the gross-motoric system, managed to read three out of five words in the end. The person who trained with the fine-motoric system, was able to read one out of five words in the end. These results have to be seen in relation with the proportion of gestures learned correctly. Here, the participants who learned the gross-motoric gestures were able to remember the majority of gestures correctly. The illiterate participant who learned the gross-motoric gestures performed 80% (five out of six) gestures correctly. Among the learners with the fine-motoric system, the literate person was able to perform four out of seven gestures correctly (57%) and the illiterate person three out of seven gestures (43%). See Figure 2 for a visualization of learning results.

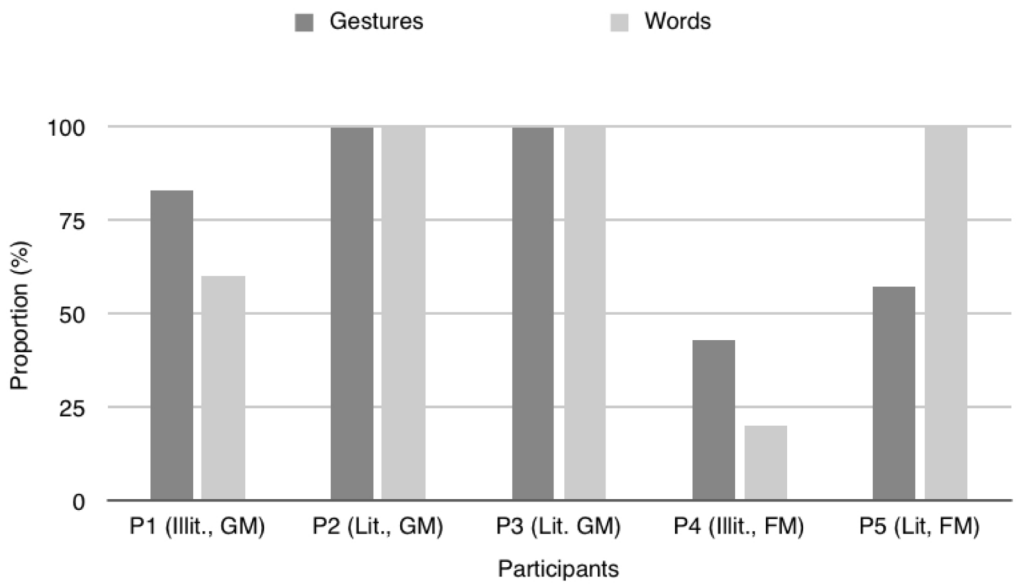

Figure 2: Learning outcome: Proportion of gestures performed correctly and words read independently and correctly at the end of training session 3. Participants were classified as literate (Lit.) or illiterate (Illit.) and learned either with a gross-motoric gesture set (GM) or a fine-motoric gesture set (FM).

Moreover, we were interested in the learning experience: How much did the participants enjoy the sessions? And is there a motivational effect to train with a gesture-based program beyond the scope of the study? Generally, all participants reported high degrees of fun. They enjoyed both, interacting with the virtual character as well as using gestures to become illiterate. One participant (who had significant problems with performing and remembering the fine-motoric gestures) reported a low degree fun with the gesture-based learning at the end of session 2, but still enjoyed the interaction with the virtual agent. Moreover, the majority of participants evinced to further train their reading abilities with gesture support apart from the fixed training sessions with the virtual agent. Only one participant (again the illiterate person who had problems with the fine-motoric gestures) raised concerns that this might be difficult especially when Billie would not be present.

We were further interested in issues that participants found helpful with respect to learning, motivation etc. Four out of five participants noted that the virtual character's explanations of letter shape and comments on peculiarities of the movement were particularly helpful. One participant put it like this "Billie's explanations were great. They helped to recognize and understand everything". It could also be observed that gestures were performed more exactly after the agent had given/repeated his explanations. Moreover, participants judged the repetitions of previously learned letters and gestures at the beginning of sessions 2 and 3 as very helpful. One participant noted that these repetition helped to gain certainty. Another comment by one participant highlighted the motivational effect of positive feedback provided by the agent: "When Billie said that I did well, I felt especially motivated. Then I wanted to proceed immediately.".

Finally, another comment by a participant stressed the beneficial effect of an *artificial* character in the role of a teacher: 'It is very embarrassing for me that I'm illiterate. In interaction with Billie this does not matter, but I do not like to talk about this with other people. And when I'm making mistakes, this does not matter in interaction with Billie as well.". This assessment highlights the advantage of a virtual agent over a human teacher given that people feel unpleasant in their role of illiterate learners.

5 Conclusion

In this paper, we presented first work towards bringing gesture-supported literacy training together a virtual human in the role of a teacher for people with cognitive impairments. In a user-centered design approach we set up several short training sessions and evaluated these with participants from the target group. Two different gesture sets came to application: A gross-motoric set developed by Bleidick & Kraft (1966) and a fine-motoric set developed by Koch (1939) (often applied in past and present classroom teaching). Overall, participants' training with the prototype was successful in the way that all of them could read at least some short words at the end of the third session. Results of the evaluation study will inform future prototype developments and improvements. These can be summarized in two major points.

First, participants enjoyed the interaction with the virtual agent and had, likewise, fun with the gesture-based training program. The majority of participants were motivated to continue the gesture-based training apart from the study. So the idea of bringing gesture-supported literacy training together a virtual human in the role of a teacher, as realized in the prototype, receives distinct support in terms of sensed fun and motivation. These issues are of particular importance for the development of a comprehensive literacy training because most of the intervention methods (courses, e-learning) which currently available are affected by decreasing motivation of participants and high dropout rates.

Second, problems arose especially from particular gestures. In the gross-motoric gesture set, only one gesture appeared to be problematic. In the fine-motoric set, there were several gestures which caused trouble. People who trained with the latter reported repeatedly that gestures were relatively hard to recognize and to imitate. We take these observations and comments as an indication to bank on a rather gross-motoric gesture set in future development. There are several likely explanations for this finding (cf. Kraft (1971)). One reason might be that people with cognitive impairments are often also motorically disabled so that gross-motoric movement are less challenging for them than fine-motoric movements. Another reason could be that gross-motoric systems provide motoric distinctions between vocals and consonants which is not present in the fine-motoric systems. This distinction might be an effective help for reading and sound synthesis. Further, in the gross-motoric gesture set, the shape of movements is related to letter shape which might also support memory performance. Moreover, evidence from human-robot interaction also provides evidence for large and exaggerated gestures to enhance memory performance, engagement and perceived entertainment value (Gielniak and Thomaz, 2012).

On the basis of these insights we will further improve and extend the prototype system and transform the present wizard-of-oz into an autonomous system. Besides work on significant challenges in speech and gesture recognition this work should also comprise work on the agent's overall verbal and nonverbal behavior. An advanced prototype should also be subject to further controlled evaluations measuring both short- and long-term learning success. Moreover, as we could substantiate in the work presented here, that employing gesture supported literacy training with a virtual character is a promising direction, we

can think of applying a similar approach for other content or domains – as one participant put it: "Maybe we could also train sign language with Billie. In gestures he is already great".

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