A manual alphabet for touchless gesture-controlled writing input with a myoelectric device

Design, evaluation and user experience

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Abstract

The research community around gesture-based interaction has so far not paid attention to the possibility of replacing the keyboard with natural gestures for writing purposes. Additionally, insight into the actual user experience of such an interaction style is only insufficiently provided. This work presents a novel approach for text input that is based on a manual alphabet, MATImyo. The hand alphabet was developed in a user-centered design process involving potential users in pre-studies, design process and evaluation procedure. In a Wizard-of-Oz style experiment with accompanying interviews, the alphabet’s quality as input language for composing electronic texts was evaluated and the user experience of such an interaction style assessed. MATImyo was found to be very suitable as gestural input language with a positive user experience. The whole process of designing MATImyo and evaluating its suitability and user experience was based on the principles of Embodied Interaction, which was chosen as theoretical framework. This work contributes to understanding the bigger picture of the user experience of gesture-based interaction and presents a novel, more natural text input method.

Keywords: Gesture-controlled writing input, manual alphabet, user experience, gesture-based interaction, Embodied Interaction, myoelectric gesture control

1. Introduction

Loris Malaguzzi’s poem “I cento linguaggi dei bambini” (“The Hundred Languages of Children”) is about the variety of ways in which children express themselves. He criticizes, that of these 100 languages, society and the educational systems steal 99 by separating the child’s mind from the body. They leave the child with only the spoken word. This poem reflects not only a very true aspect about our society, artificially restricting the nature of us, humans, by socio-cultural norms, its critique can also be transferred to the monotonous way we interact with the computer in the pursuit of our everyday computer routines. But what, if
we had a choice? What if there was a more versatile and adaptive – “human” – way for accomplishing our daily tasks on the computer? What if we could even write on the computer without the burden of being bound to the desk and getting engaged with the keyboard?

1.1 A future scenario
Imagine coming home tired after a long day of work. All you want now is to relax and you get comfortable on the couch. Suddenly, you remember that you forgot to answer to this email that needed to be sent today. While you remain in your relaxed position, you turn on the huge screen by saying “Screen on!” Then you open the email program in a similar way and start writing an answer by performing small hand signs with your right hand. Your back, neck and shoulders are relaxed and only the hands and occasionally one arm are working in tiny movements, while you monitor your writing on the big flatscreen, supported by autocomplete and autocorrect. Then you decide to watch TV and signal your desire to the interactive system by saying “TV on!”. You choose the right channel and adjust the volume by gestures, hardly noticeable. The next morning, on your way to work, you want to write some stuff on your shopping list. So, you put on your interactive glasses and start adding items by using a sign language with tiny movements of your right hand. At work, you have to give a presentation which you, of course, control with gestures while you move freely in front of the screen, scrolling through the slides and making digital notes through hand signs along the way, which your notebook receives for further processing later.

1.2 The need for a gestural writing interface
With a multimodal interface affording a repertoire of natural interaction styles, as described in the scenario above, the interaction with the computer would be more comfortable, mobile and adaptive. Being able to choose between interaction styles affords the user to adjust the interaction to the current needs in a particular use context. In a world where we are surrounded by interactive devices and with technology tightly intertwined with our daily routines, it is essential to provide interactive systems that do not interfere with our expectation of how a certain activity should feel like. Ideally, there would be no difference between the way we interact with an object in the real world and its virtual representation. This idea is manifest in the work of Dourish (2004) about Embodied Interaction. He questions the suitability of traditional interaction for the human user, marking the standard interface of keyboard and mouse as unnatural. Instead, he suggests an approach towards involving our tangible and social interaction skills when communicating with the computer, since this is the way we also interact with the real world. One way for bringing the computer closer to the needs of a human user is to exploit our ability to communicate through gestures. Gestures are a fundamental part of the natural human language, which consists not solely of the spoken word, but is a composition of speech and body language, intimately intertwined (McNeill, 2012). In certain cases, gestures can even replace speech, for example when giving someone “the finger”. In fact, gestures are so significant in our everyday usage of language that we gesticulate even when our conversation partner is not physically present, for example when talking on the phone (Rimé, 1982).

1 More about Embodied Interaction can be found in section 2.
However, the meaning of gestures is often not intuitive (Norman, 2010), except from gestures like pointing, moving things and direct manipulation. They need to be learned like the spoken vocabulary and can vary across cultures. And still, that does not make the expression form any less innate. We have a natural drive to make ourselves understood through body language from the very moment we come into this world. It comes so natural to us, that even eight-months-old babies can express simple words of their everyday lives in gestures, before they learn to talk (Bonvillian and Folven, 1987). Therefore, it seems intuitive to us, and that is the decisive aspect for promoting gesture-based interaction for an improved interaction experience.

A frequently used definition of gestures in the context of HCI is the one by Kurtenbach and Hulteen (1990):

“A gesture is a motion of the body that contains information. Waving goodbye is a gesture. Pressing a key on a keyboard is not a gesture because the motion of a finger on its way to hitting a key is neither observed nor significant. All that matters is which key was pressed”

This definition is adopted in this work, however limiting the focus on touchless manual gestures, i.e. meaningful movements of the hands without surface contact with a device.

In order to afford the user a natural interaction experience, both unobtrusive technology for recognizing and processing the gestural input, and a suitable, human-oriented gestural input language are required. Computers have made great progress in understanding various forms of natural language, including gestures and sign language. It is now the call for the developers to provide us with gesture vocabularies that let us accomplish common computer tasks through meaningful gestures in order to encourage potential users to take the step out of the comfort zone provided by the standard interface, and to adopt this new interaction style, not only for games and physical exercises, but for all kinds of everyday computer applications. Since composing electronic texts is one of the most important computer tasks, a successful gestural interface needs to provide such a functionality as well. In the scenario, a solution based on a gestural alphabet fulfilled this function, granting the user a convenient and mobile interaction alternative for text input. This approach seems promising and, thus, needs further investigation.

1.3 Research question and purpose

The success of gesture-based interaction is highly dependent on the way it is realized through technology and input language. While the majority of the research community focuses on the technological solutions for gesture recognition or the generation of gesture vocabularies to accomplish mouse-related tasks in spatial and manipulative applications², very little effort is put into developing a gesture-based replacement for the keyboard. However, without the possibility to compose texts, it is very likely that potential users are rejecting the whole concept, since they would need to switch to another interaction mode whenever text input is needed during their computer work. Furthermore, as long as gesture-based interaction cannot provide all functions of traditional interaction, it is hard to tell, how engaging in

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² See section 3.
everyday computer tasks with such an interface would actually feel for the user. The user experience, however, is a crucial aspect about interactive systems, that all designers and developers need to regard in order to produce comfortable and convenient interfaces (Benyon, 2010). In other words, there is a need to both find a solution for entering text via a gestural interface for practitioners, and to determine its hedonic and pragmatic qualities³ for researchers, developers and designers. Hence, one part of this work focuses on developing a gesture vocabulary for accomplishing writing tasks of all kinds on the computer. The other part aims at answering to the research questions that emerge when such a gestural input language is put in place:

1. How suitable is the alphabet resulting from the design process in this work for the task of composing text on the computer?

2. What is the user experience of using gesture-based interaction for writing input?

By investigating the first concern, valuable aspects about the design criteria for gestural writing alphabets can be derived, hopefully leading to future input interfaces that feel more natural and intuitive for the user.

The second research question is consciously posed more openly, since a user test with the particular alphabet could independently of its quality reveal aspects about the interaction style itself. So far, the whole picture of gesture-based interaction could not be seen because of the lack of a suitable gestural writing input. This work aims at contributing to closing this gap and, thus, shedding some light on potential users’ motivations for either choosing or rejecting this gestural interaction style per se, or the developed gesture alphabet in particular. Before learning about the bigger picture, important issues with this interaction style might be left untouched. With the results derived from this work, the focus of future research regarding gesture-based interaction might be directed towards addressing new aspects about gestural interfaces, paving the way for an enhanced user experience through human-friendly interaction.

1.4 Outline

Firstly, the theoretical framework underlying the design work and evaluation of the alphabet is described in section 2, followed by an overview of related research in section 3., setting the scientific scene for this work. Section 4 gives detailed insight into the process of designing the manual alphabet for gestural writing input, including several pre-studies from which design criteria were derived. Here, also the actual creation of the alphabet and the final result are presented. The quality of this alphabet as well as the user experience of using it in a real-life scenario is evaluated in section 5, and the results are presented in section 6. Section 7 discusses the results and also gives suggestions for future research. Finally, the conclusion of this work is revealed in section 8.

³ The user experience consists to a great extent of user-perceived usability (i.e., pragmatic attributes), and hedonic attributes (e.g., stimulation, identification, fun, aesthetics) (Hassenzahl, 2004)
2. Theoretical framework: Embodied Interaction

Creating an interface that has a natural feeling to it is not an easy task. Therefore, Embodied Interaction was chosen as theoretical framework that could provide a helpful perspective during the evaluation and interpretation phase of the study. It was found suitable as guidance on this journey, since it aims at enhancing the user experience by putting the user first, taking into account our human skills and meaning making mechanisms, instead of limiting our communication to the requirements of the machines. Placing this work within the theoretical framework of Embodied Interaction provides the ground from which human-centered design and evaluation can arise, leading to results that are in compliance with the actual needs and concerns of potential users. This is a core ingredient for a positive user experience from which this work will certainly benefit. In the following, Embodied Interaction is introduced and important aspects for this study are highlighted.

Paul Dourish coins the term “Embodied Interaction” in his book “Where the Action Is: The Foundations of Embodied Interaction”. He defines embodiment in the following way: “Embodiment is the common way in which we encounter physical and social reality in the everyday world. Embodied phenomena are ones we encounter directly rather than abstractly.” (Dourish, 2004, p. 100). Departing from this phenomenological view on embodiment, he elaborates the close relationship between action and meaning and the participative status of interaction, and concludes: “Embodied Interaction is the creation, manipulation, and sharing of meaning through engaged interaction with artifacts.” (Dourish, 2004, p. 126).

This means that Embodied Interaction is about direct physical and social interaction with the computer, exploiting our natural human skills and experiences with the real world. It seeks to adopt the ways in which we humans interact with each other and the world through our everyday practices.

Furthermore, the concept of Embodied Interaction lays heavy weight on the relationship between action and meaning. We find meaning through our actions, and out of meaning, new actions can arise. As meaning and, thus, our understandings of the world is highly dependent on our own experiences and social context, designers of embodied interfaces have to deal with issues concerning intersubjectivity, ontology and intentionality. How can a user interface be designed in order to not only work for one individual or a “community of practice\(^4\)”, but for everybody? How can the interface be designed in order to reveal the system’s functionality to the user? And how can we act through the interface and the technology to achieve the desired effect in the real world?

While Dourish leaves a lot of room for interpretation with his notion of Embodied Interaction, the community of HCI designers seems to have agreed on two interaction styles that can be held as Embodied Interaction: interaction that feels natural and interaction that is conducted through the body. Embodied Interaction implies that the interaction happens effortless. This does not mean physically effortless in first place, but rather cognitively. The user would not have to think more when performing a certain action on the computer than

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\(^4\) “Communities of practice share histories, identity and meaning through their common orientation toward and participation in practical activities.” (Dourish, 2004, p.186)
would the same kind of action in the physical world require. Furthermore, only interacting
with the computer through the body, because it is exciting, is not enough in order to count
the interaction as embodied when thinking about Dourish’s discussions about accountability,
shared meaning and intentionality. According to him, it is only to be called embodied, if there
is any kind of meaningful coupling involved. That means that the action executed in order to
interact with the computer for a certain task has to be meaningful to the user and others also
in the real world, not only in the virtual. Without meaningful interaction, someone who was
to engage in simple natural language or body interaction would have to put extra effort into
learning the new interaction style. However, body and natural interaction form a good base
to start from when designing an interactive system that promotes the users’ innate
interaction skills. With some modifications according to Dourish’s notion of Embodied
Interaction, intersubjective meaning can be introduced to the interaction, which supports the
user in understanding how the system works. To this end, the designer needs to establish a
common ground of shared meaning between users, but also between user and designer,
becoming manifest in the resulting design. This is a critical aspect about Embodied
Interaction and guided the designer in this work throughout the design and evaluation
process when choosing appropriate design and research methods for the task at hand, and
when interpreting the results. The framework did also influence the selection of related
research that was considered as scientific base for this work, since approaches that do not
promote the human interaction skills were not relevant for this study and could be neglected.
The next section is summarizing the related research and identifies the research gap which
this study aims to fill.

3. Related Research

The history of gesture-based interaction started in 1963 with Sutherland’s pen-based drawing
interface “Sketchpad” (Sutherland, 2003). The research community can now look back to a
more than 50-year-long history of research and experimental projects. However, it was not
until the late 1970’s and early 80’s until the research around touchless gesture-interaction
began to blossom with early works of Krueger (“VIDEOPLACE”, Krueger, 1983) and Bolt
(“Put-that-there”, Bolt, 1980). Since that, countless and versatile approaches have been
explored for making the human-computer interaction through touchless gestures possible.
Myers (1998) as well as Karam and Schraefel (2005) provide some more detailed
presentations of developments in the area of gesture-based interaction, including enabling
technologies, gesture styles and application domains. This thesis, however, is only concerned
with research and projects with focus on 1) touchless gestures or sign language for text input,
2) the user experience of gesture-based interaction, 3) natural gestures for human-computer
interaction, and 4) myoelectric gesture control.

3.1 Touchless gestures or sign language for text input

Sign language and national spelling alphabets have been subject for research around
gesture-based interaction for at least 30 years (Zimmerman, Lanier, Blanchard, Bryson and
Harvil, 1987). The intention with this kind of research is primarily to support deaf and
hearing impaired people (e.g. Brashear, Henderson, Park, Hamilton, Lee and Starner, 2006; Madeo, 2011; Dangsaart, Naruedomkul, Cercone and Sirinaovakul, 2008; Chen, Li, Pan, Tansley and Zhou, 2013). Their focus lies heavily on the technological solutions and algorithms for recognizing and interpreting the gestures correctly (e.g. Starner, Weaver and Pentland, 1998; Li, Chen, Tian, Zhang, Wang and Yang, 2010; Ibarguren, Maurtua and Sierra, 2010; Sun, Zhang and Xu, 2015; Madeo, Peres, Dias and Bosciarioli, 2010; Dimov, Marinov and Zlateva, 2009), since the input vocabulary, i.e. the official national sign languages, is determined from the beginning. Other, most of all early research projects involving sign language or spelling alphabets are exploiting the fact that they are already existing gestural systems that can be re-used for human-computer interaction in general (e.g. Takahashi and Kishino, 1991; Zimmerman et al., 1987).

However, the production of text through sign language is rarely considered as main focus. There is some effort put on converting sign language into text in order to meet the needs of deaf people (e.g. Dreuw, Forster, Gweth, Stein, Ney, Martinez, Verges Ilahi, Crasborn, Ormel, Du, Hoyoux, Piater, Moya Lazaro and Wheatley, 2010; Nahapetyan and Khachumov, 2014, Dangsaart et al., 2008), but not for common computer applications, where aspects of efficiency, disambiguation and learnability play an important role. Ren, Men and Yuan (2011) use a set of ten hand gestures as numeric input for a Sudoku game. Again, the choice of the gestural input language is almost arbitrarily made and only serves for testing and demonstrating the hardware/software solution.

However, there are other approaches for entering texts via touchless gestures that are not based on a national sign language. Possible solutions are airwriting (e.g. Amma, Georgi and Schultz, 2014; Fujitsu Laboratories Ltd., 2013), enabling the users to apply their normal writing skills without having to learn any new input language, and Swype keyboards with gestural input (Swype) that allow the users to write on a virtual keyboard by touchless swipe gestures across the letters. Another way for replacing the keyboard through manual interaction is using a glove keyboard. A data glove on one hand enables the user to enter texts by touching different positions on the palm and fingers with the thumb, triggering the input of the corresponding letter that is assigned to this spot. Already working glove keyboards are KITTY (Mehring, Kuester, Singh and Chen, 2004) and Gauntlet (University of Alabama Huntsville, 2012). The approach has recently been deeper investigated by Omran (2014) in order to find out about the best position for touch spots on palm and fingers. He points out that while glove keyboards are based on the same unnatural concept as the keyboard, it might be easier to blindly target the right spots on your body exploiting our proprioceptive skills than on an external device. Another advantage with such an approach is according to Omran, that you are mobile, while you type texts with one hand, leaving the other hand free for whatever is needed on the go.

3.1.1 Discussion

For the purpose of this work, none of the here described existing research projects that are based on a national sign language are of any particular relevance other than the simple fact that they confirm the technological possibility for sign language recognition and interpretation. Firstly, they do not provide insight into the suitability of sign language or spelling alphabets for common users and everyday computer applications; secondly, since
the input language is given, no further development is needed, and thus, no design criteria for a sign-language-based approach is provided; and thirdly, using existing sign language alphabets as they are would not be an option either, since they are generated with a human conversation partner in mind, not a machine that has other requirements.

Approaches like airwriting and Swype keyboards that require the user to lift the arm and point towards the screen for interaction are obviously leading to fatigue in arms and shoulders. Swype keyboards have the additional drawback that the user has to use a virtual keyboard, which is exactly what this study aims to replace. However, the glove keyboard approach provides some valuable benefits for the users, as mentioned above. Additionally, due to their technological design, no visual contact or particular orientation of the hand is required either, allowing for a flexible and relaxed working position. These advantages over the standard interface are a valuable source for inspiration regarding the conceptual base for the design approach of this work.

3.2 The user experience of touchless gesture-based interaction

At this point, only little is known about the user experience of touchless gesture-based interaction as interaction style per se, since the major part of the research effort is put into evaluating the pragmatic and usability aspects of a system. Only a few researchers have so far assessed or predicted the user experience for a specific application. The majority investigated the user experience of gesture-controlled gaming (e.g. Williams, Brewster and Vennelakanti, 2013; Yan and Aimaiti, 2011), but also other areas were considered, ranging from applications in automotives (Loehmann, Diwischek, Schröer, Bengler and Lindemann, 2011) to interactive urban environments (Giovannella, Iosue, Moggio, Rinaldi and Schiattarella, 2013). While they describe very context- and task-specific user experiences, they have in common that the technology on which the testing was based was either imperfect prototypes or outdated with respect to current technological performances. On the other hand, the results were quite homogenous, reporting a general positive user experience, since it was perceived to be more enjoyable and natural to use the body instead of a device. This was also supported in a study conducted by van Beurden, Ijsselsteijn and de Kort (2011). They compared the user experience of gesture-based interaction with traditional interaction in mouse-related tasks and found out that the first one is favored in terms of hedonic qualities, and the latter one in terms of pragmatic qualities. While this indicated the suitability of gesture-based interaction for replacing the mouse, it cannot simply be transferred to gestural keyboard supplements, since the type of tasks are too different from each other.

Also acceptability of gesture-based interaction has received attention by the research community (e.g. Rico and Brewster, 2010; Williamson, Brewster and Vennelakanti, 2013), directing the focus on the perceived appropriateness of the application of gestures in different social settings.

3.2.1 Discussion

It is impossible to make generalizations from the results described in the studies presented above, since they reflect a very particular, context- and task-specific user experiences.

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5 For further information, see section 4.
Additionally, it is hard to predict how the results would have looked like, if the studies were conducted with a technology according to the current performance standard or a mature system. Certainly, it can be assumed that the results would have been less biased by technological shortcomings. For this reason, the results from the existing studies can only hint about a general user experience of gesture-based interaction. Since there is no existing system for entering letters via a manual alphabet in everyday applications yet, no information about the user experience of gestural writing input in particular is available either. There is a need to fill this gap with an approach that does not have to deal with issues of a specific technology in order to be able to report about a “clean” user experience of the interaction itself, both in general and in the context of a writing task.

3.3 Natural gestures for touchless human-computer interaction

As already mentioned, a lot of the research community’s efforts for generating gesture vocabularies in the context of human-computer interaction was put into making the system work and, thus, designing or choosing gestures that are reliably identified by the machine. Now that the technologies have become more powerful and inexpensive, and with the rise of the Kinect even made their way from the laboratories into the homes of ordinary people, more focus needs to be set on the human part of the equation. This concern is not novel. As early as 1993, Baudel and Beaudouin-Lafon (1993) offered guidelines for identifying natural gestures, meaning here “those that involve the least effort and differ the least from the rest position”. They suggested an iterative procedure involving test users. Hummels and Stappers (1998) demonstrated the feasibility of intuitive gestures for human-computer interaction in a proof-of-concept Wizard of Oz experiment. However, they do not clearly specify their notion of “intuitive” or “meaningful” gestures more than that those gestures were accurately interpreted by the human operator in the experiment. Almost at the same time, Cassell (1998) developed a framework for generating and interpreting natural, coverbial gestures as a part of a multimodal interface that also regards speech and facial expressions as input means.

Nielsen, Moeslund, Storring and Granum (2004) presented a procedure for developing intuitive and ergonomic gestures for human-computer interaction, inspiring many other researchers to follow and refine this approach (e.g. Epps, Lichmann and Wu, 2006; Wobbrock, Morris and Wilson, 2009; Micire, Desai, Courtemanche, Tsui and Yanco, 2009; Heydekorn, Frisch and Dachselt, 2010; Grandhi, Joue and Mittelberg, 2011). At the base of the procedure is the idea to let the test users elicit appropriate gesture sets relying on their intuition. Due to this approach meeting the expectations of the end-user, the procedure, or parts of it, have been adopted for the development of user-defined gesture sets in contemporary projects as well, ranging from input gestures for smartphones (Ruiz, Li and Lank, 2011) and TV sets (Vatavu, 2012) to multi-touch and tangible interfaces (Valdes, Eastman, Grote, Thatte, Shaer, Mazalek, Ullmer and Konkel, 2014).

Henceforth, the expression “clean user experience” is applied to indicate a user experience that is not affected by bias from specific technological solutions, typical problems of beginners or abnormal circumstances of the use context in order to reflect the experience a typical advanced user of a working system might have in the future.
Another methodology for deriving gestures for natural interaction is proposed by Stern, Wachs and Edan (2008), pointing out that the optimal design for natural hand gestures is a multi-objective decision problem. It is about the balance between comfort, intuitiveness and recognition accuracy, an equation which they solve with the help of a computer program that compares these values for different alternatives derived in a user test.

Significant contributions to the understanding of natural, touchless gesture interaction from an Embodied Interaction point of view were made by Grandhi, Joue and Mittelberg (2011 and 2012). They investigated the ways in which humans express transitive actions, i.e. actions manipulating objects, through gestures and how we make meaning out of the gestures we are presented with. In (Grandhi, Wacharamanotham, Joue, Borchers and Mittelberg, 2013), they take a step back and look at the bigger picture of how we treat the computer differently than human communication partners when we are using gestures, by this even contradicting the media equation (Reeves and Nass, 1998).

O’Hara et al. (2013) are approaching the issue of natural gestures for human-computer interaction with a perspective that is even more oriented towards Embodied Interaction. They are proposing to not only see the gestures, the human and the computer as individual parts of the human-computer interaction, but to regard them as a unit, situated in the social context from which the actual, current naturalness can arise.

3.3.1 Defining naturalness of touchless gesture interaction

Reviewing the literature about natural gestures for human-computer interaction, it becomes clear, that this expression is used in different nuances of what we would consider natural. O’Hara et al. (2013) pointed out that the term natural has often been used as merely a synonym for “easy to use” and “easy to learn” (e.g. Wachs, Kölsch, Stern and Edan, 2011). While this might be a consequence of the truly natural gestures, it is not what defines them in first place, according to most of the researchers investigating this subject more thoroughly. The common ground on which they build their works was the idea that simply using gestures in interaction is not enough in terms of naturalness or intuitiveness (e.g. Norman, 2010). Suffer explained in the true spirit of Embodied Interaction that the “best, most natural designs, then, are those that match the behavior of the system to the gesture humans might actually do to enable that behavior” (Saffer, 2009, page 29). In other words, it is what humans do in their everyday life, in the particular context and for such a purpose, that should define the way we communicate with the computer, not the requirements of the machine. Grandhi, Joue and Mittelberg (2011) concluded that natural is “marked by spontaneity and ‘intuitive’ as coming naturally without excessive deliberation”. Hence, what occurs frequently and spontaneously in common tasks can be considered natural and intuitive. However, Norman (2010) pointed out that even learned behavior can appear natural or intuitive to us, including behavior we applied for decades with the standard interface. The question is, if this is truly natural and helping the human operators on the long run or only convenient for the users of this generation who have experienced the traditional interaction styles.

O’Hara et al. (2013) went even further and explained that it is not the gesture itself and its common meaning that makes it natural. Naturalness comes from the fact that we find and make new meaning by using the gestures when interacting with the machine. They proposed that instead of limiting the notion of naturalness to the experience of the “objective body”, i.e.
the physical expression of the gesture and its common meaning, it needs to be extended to the “lived body” through which subjective and shared meaning is found and established in situ, making us understand the world in new ways as a result of the experiences of the “lived body” in this particular situation. The gestures need to be constituted by the context, not brought to it.

Considering the theoretical framework of Embodied Interaction that guides this work, a definition according to Grandhi, Joue and Mittelberg (2011) as well as O’Hara et al. (2013) is adopted. Henceforth, gestures are considered to be natural, if they feel intuitive to the current user for the task at hand. Thus, the fact that a gesture is considered natural for a certain user in a certain situation does not necessarily mean that the same gesture is perceived intuitive in another situation or by another user. It is at the core of the design work of the manual alphabet7 to find ways to develop the gesture vocabulary in a way that maximizes the feeling of naturalness for as many users as possible.

### 3.3.2 Discussion

All of the projects mentioned above focused on manipulative actions, which are mainly referring to typical mouse tasks (e.g. arranging or rotating items and opening folders, turning on a device), and thus, their findings cannot be simply applied for the purpose of creating a hand alphabet with the non-transitive task of expressing a letter. However, the way they approached the task of deriving gesture vocabularies that are in accordance with the user expectations based on Nielsen et al.’s (2004) procedure can still serve as guiding example for the design work on the manual alphabet8, since the presented view on naturalness requires the involvement of potential users in the design process in order to achieve an interaction that is based on shared meaning and intersubjectivity. Also Stern et al.’s (2008) method for selecting the final gestures from the user-elicited alternatives by balancing several criteria for a successful result seems promising for the purpose of this work, where user-centered aspects and technological constraints need to be taken into consideration.

### 3.4 Myoelectric gesture control

Myoelectric gesture control devices are affording the user a more private or subtle interaction with the technology, since the sensors that are attached to the arm, are picking up the signals from the muscles even if the contractions are very brief and only a small movement is performed (Costanza, Perdomo, Inverso and Allen, 2004). Also in this research area of gesture-based interaction, the focus lies primarily on developing the hardware and software solutions enabling gesture control (e.g. Chu, Moon and Mun, 2005; Wheeler, 2003; Li, Chen, Tian, Zhang, Wang and Yang, 2010). Efforts are also put into finding a suitable position on the arm to place the sensors for the best possible signal reception from the muscles (e.g. Peters, 2014). So far, there is no research done in designing a gesture vocabulary that fits the potential of such devices9.

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7 See section 4
8 See section 4.3
9 The properties and potential of gestural interaction with myoelectric devices is further discussed in section 4.1.3
3.4.1 Discussion
The research efforts within myoelectric gesture control are not significant for this work, since they are not concerned with the design of meaningful gestures.

3.5 The research gap
Summarizing the related research presented above, it is obvious that there is a need for further research. Firstly, the contributions about the user experience of gesture-based interaction are either outdated, too task-specific, not including everyday computer tasks or biased by technological issues. Secondly, there’s no gestural input language designed for using a myoelectric control device available yet. Thirdly, none of the touchless keyboard supplements are based on static, iconic freehand gestures, i.e. a manual alphabet that can be applied in a convenient way. And finally, the focus of enabling gesture-based interaction lies mostly on the technological part of the equation, and the little effort that is put on the user part is limited to mouse-related tasks.

This work aims at closing the research gap: by reporting about the “clean” user experience of everyday keyboard-related tasks accomplished through an intuitive, manual alphabet, one more piece of the puzzle portraying human-friendly interaction with the computer will be put in place. The next section describes the design process of the hand alphabet and the resulting gesture set is presented.

4. Designing the manual alphabet MATImyo
This section provides insight into the design process of MATImyo, a manual alphabet for touchless human-computer interaction with a myoelectric gesture recognition device, that was developed within this work. Since the theoretical framework of Embodied Interaction suggests a design that is based on shared meaning and intersubjectivity, resulting in an interaction style that is in first place adapted to the users’ needs, not the technology’s, a user-centered design approach was adopted. Hence, the design process consisted of 1) several pre-studies for getting acquainted with the design context, 2) the determination of suitable design criteria, 3) the selection and generation of proper hand signs in co-creation with users, and finally 4) the definition of the resulting alphabet. A short discussion giving a critical perspective on the process and the results completes this section. For clarification: the author of this work is in this section referred to as “designer” according to her role in the process.

4.1 Pre-studies
For a successful result, i.e. a manual alphabet that is easy to learn, easy to perform, easy to recognize by the technology and most of all meeting the user expectations, a series of pre-studies was conducted in order to get acquainted with the users, the subject of communicating through gestures and the available technology. The pre-studies served the purpose of delivering the underlying requirements to which the resulting design needed to answer. Below, a summarizing view on the conducted pre-studies from which the design criteria for MATImyo were derived, is provided.
4.1.1 Understanding the user expectations

As pointed out by Courage and Baxter (2005, pp. 3-5 and 41), it is important to know the potential users and their requirements in order to develop a successful product. Hence, the users should be involved in the design process from an early stage. In order to get feedback from potential users about their experiences with, expectations of and prejudices against gesture-based interaction and gesture controlled writing with sign language in particular, a survey study with 67 respondents was conducted. The subjects were recruited via Facebook, where an invitation to the study was posted both on the designers personal page and in several open groups for reaching out to a greater and more versatile amount of potential participants (Tan, Forgasz, Leder and McLeod, 2012). Hence, some of the subjects were known to the conductor, at least on Facebook, while some were complete strangers with respondents from around the globe. The results most relevant for this study are provided in the following.

The majority of participants have never had contact with any technology for touchless, free-hand gesture-based interaction before, except for game consoles. Their experiences with those were “okay” for gaming purposes, but they were unsure, if this interaction style would be suitable for everyday computer tasks. The main reasons for this were the respondents’ skepticism about the technological reliability concerning gesture recognition and efficiency with work-related tasks, as well as the effort of having to learn a sign language, physical fatigue and privacy issues. However, the majority of subjects was open towards trying this new interaction style for everyday computer tasks. A crucial criterion of such a gesture interaction technology was considered to be the possibility to replace the keyboard for tasks like composing texts and programming. For this, a letter-based writing input was required in order to not be limited by pre-defined word-based signs, but to be able to write whatever is desired.

4.1.2 Understanding the use of sign language in everyday life

Being rather inexperienced in sign language, it would be hard to estimate its learning curve and the effects of frequently using it. Thus, in order to be able to answer to the prejudices about extended usage of gestures expressed by the participants in the survey, it seemed crucial to explore this way of human-to-human communication further. To this end, the designer studied and practiced the basics of several national sign languages with corresponding spelling alphabets and conducted semi-structured interviews with two sign language experts. This was complemented by a literature study about sign language and gestures in general.

Engaging in sign language has the advantage of not only understanding the constituting components like grammar and vocabulary intellectually, but also exploiting the human skill of developing a sense for a language on a much more subtle level. This tacit, or in the case of sign language even embodied knowledge can later be used as support for making the right design decisions just out of gut feeling.

The experts in this study were two teachers for sign language at a local adult education center. One of them was a native signer, the other one learned sign language as an adult and worked as an interpreter as well. Being practitioners of Swedish Sign Language on a daily basis, the experts provided a valuable insider perspective on aspects of sign language, such as
the effects of signing frequently and extensively. In their role as sign language teachers, they also knew exactly how a typical learning curve looks like. The most important findings from this pre-study are presented as follows.

Addressing the test users’ prejudices against extensively using sign language or gestures for interaction, the experts confirmed that many sign language interpreters suffer from physical disorders in shoulders, arms and hands, since they often have to translate long speeches or presentations without a break. This is also supported by a questionnaire study of Rempel, Camilleri and Lee (2014) including 24 experienced sign language interpreters. However, in a typical human-to-human conversation via sign language, turn taking and natural pauses prevent these negative effects. Furthermore, expert signers are usually adapting a sloppier, more ergonomic-friendly style, increasing efficiency in signing in several ways: 1) not executing the whole movement or orientation of the hand, 2) leaving out the vowels in spelling and 3) aggregate several signs in one, similar to stenography. The teachers also pointed out that a word-based sign language would in most of the cases be more efficient than the written or spoken language, but could not say the same about a letter-based spelling approach. Concerning the learning curve, people tend to be surprised how fast and easy it is to learn the basics of sign language, according to the experts. They see no reason why potential users should not be able to learn an interaction sign language.

4.1.3 Selection of an appropriate gesture recognition technology
Knowing that there are various gesture recognition technologies with different demands on the user performance and surroundings on the market, it was considered essential to determine which of the available solutions will be the most suitable for realizing the scenario previously described in section 1.1, in order to adapt the design criteria according to the technology’s potential or limitations. After an initial Internet research, only the Microsoft Kinect, the LEAP motion controller and the MYO armband were able to recognize touchless gestures on finger level, while being robust enough and commercially available. The Kinect and the LEAP were kindly provided for further examinations by the Interactive Institute Umeå, as well as the Department of Informatics and HUMlab at Umeå University. The MYO was already in the possession of the designer and tested before. It turned out that vision-based systems, like Kinect and LEAP, in general are less suitable when having in mind to freely choose a comfortable operating position or being able to work on the go, since they require the user to stay within an active zone for the cameras to detect, and because of their dependency on a static background with enough lighting. Furthermore, only MYO worked sufficient enough in detecting the movements on finger level, but was limited to only work with five particular gestures that were predefined by the developers. However, the potential of this myoelectric gesture recognition device for being able to fulfilling the vision of an interaction style that supports the user in any preferred working position, while providing a human-friendly interface was striking. Hence, the MYO armband was chosen as technological backbone of the interactive system for which MATImyo was developed. It has additional advantages over the vision-based systems, namely the fact that the myoelectric signal from the muscles is picked up even before the gesture is performed, which makes the recognition process even faster (MYO). It also allows for smaller and sloppier gestures, that do not need the hand posture to be in a certain orientation, since the MYO understands the
hand shape from the muscle contractions not the visual feedback. Additionally, since MYO is attached to the forearm, it does not interfere with the movements of the hands and, thus, has the potential to enable natural, touchless gesture control, providing for a more efficient and ergonomically-friendly interaction.

4.2 Design criteria for the manual alphabet

Some researchers have developed guidelines for achieving natural and meaningful gestures for human-computer interaction. However, those guiding principles and design criteria are often related to mouse activities, i.e. transitive actions (e.g. Grandhi, Joue and Mittelberg, 2011). Additionally, they are regarding the interaction with a vision-based system (e.g. Rempel, Camilleri and Lee, 2004). In the case of MATImyo, neither does the input for writing classify as manipulative or spatial task, nor is it necessary to perform the gestures accurately and visible for the visual sensors. Thus, their findings can be considered only marginally.

Summarizing the results from the pre-studies as well as from the literature study of related research, and having in mind the theoretical framework of Embodied Interaction, design criteria suitable for a successful realization of a manual alphabet for human-computer interaction with a myoelectric gesture recognition device were defined. They were formed with two different perspectives, in order to meet the requirements of both the technology and the human operator.

User-centered design criteria

Focusing on the user, the most important requirements on MATImyo are related to it being ergonomically-friendly, efficient and low in the cognitive effort when learning or using it. In order to accomplish a low cognitive load, the letter representations need to fit within the framework of Embodied Interaction. This means in the case of MATImyo that the individual gestures need to be meaningful for the user and others in the same community of practice (shared meaning). Thus, the signs are easy to learn and to remember, saving the cognitive capacity for the actual content of the writing task. Additionally, a cohesive design language for each letter representation is desirable permitting to maintain the flow while signing and also preventing possible confusion about signs that somehow do not fit the appearance of the rest. This is crucial especially for letters that are perceived to be similar in a certain way and can also contribute to speed up the learning process.

Ergonomically-friendly means that the hand shapes representing the different letters as well as transitions between them need to be easy and quick to perform. This is especially crucial for frequent letters or letter combinations. The gestures need to be adjusted to the human physiology, taken into account how the joints on arms and hands move. A comprising list about comfortable and uncomfortable hand and finger postures can be found in (Rempel, Camilleri and Lee, 2004). An important aspect is also to be able to maintain a comfortable position and work throughout a long period of time (Baudel and Beaudouin-Lafon, 1993). Therefore the gestures need to be as small as possible, while still recognizable for the recognition unit.

Even though Grandhi, Joue and Mittelberg (2011) found that the inclusion of motion in the gestures for transitive actions makes them feel more natural, the major part of MATImyo
is kept static in the absence of such actions, increasing efficiency (no extra time to execute the motion) and convenience (no extra effort for executing the motion, e.g. raising the arm). Only a few hand signs for punctuation or text editing can be seen as transitive actions, so that Grandhi, Joue and Mittelberg’s (2011) key guiding principles for the design of touchless gestures involving transitive actions can be applied, suggesting that gestures for such functions are pantomimic, habitually performed, dynamic and bimanual.

Another aspect that was consciously disregarded, is the fact that word-based signing is far more efficient than letter-based. However, the pre-study showed that users require a letter-based system for crucial everyday computer tasks and having to learn only about 30 signs instead of thousands might encourage their motivation to learn the new interaction style. In order to counteract the loss of efficiency through a letter-based approach, stenographic traits could be included in the alphabet, as the sign language experts described many deaf are practicing in their everyday communication.

Increasing convenience, MATImyo is suggested to exclude non-manual signs with other body parts and to be performed single-handed to the greatest extent. Several user tests showed that one-handed gestures are preferred (Vatavu, 2012), (Wobbrock, Morris and Wilson, 2009). Moreover, since the semantic is limited to be expressed with the dominant hand, the other one is free to adopt the role of the keyboard’s function keys, e.g. shift and control. Single-handed signing makes it also easier to adapt to different use situations, e.g. operating a device on the go. Further, the hand signs need to be performable in any working position the user chooses and also be culturally acceptable in any typical use context.

**Machine-centered design criteria**
From a machine-centered perspective, the signs of the alphabet need to be distinctive enough that MYO would recognize them in any operation position the user chooses and no matter the personal variation in signing. That means free from orientation-requirements and doublets. In many national sign language alphabets, there are representations for different letters that are actually the same hand shape, just one is upside down. For MATImyo, all hand shapes need to be unique. Such unique forms are supposed to be correctly identified, even when the user signs sloppy with very small gestures. Finally, very significant hand gestures reserved for replacing mouse interaction should not be included in the alphabet. In particular, the pointing index finger is to be avoided in order to not intervene with the “mouse” gestures.

In practice, the resulting hand alphabet is a compromise of all of these design criteria. In order for MATImyo to provide a natural interaction experience, there needs to be a balance between comfort, hand physiology and gesture intuitiveness (Stern, Wachs and Edan, 2008), while providing distinctive hand shapes for accurate gesture recognition. The process of finding and selecting hand shapes in accordance with these design criteria, as well as the resulting gesture alphabet is presented in the following.
4.3 Selection of potential hand shapes with test users

As emerged from the review of related research concerning the generation of natural gesture vocabularies\textsuperscript{10}, the greatest success is achieved, when involving potential users in the creation process. Based on Nielsen et al.’s (2004) suggestion of a procedure for developing intuitive and ergonomic gesture vocabularies for human-computer interaction, several researchers adopted this approach and confirmed the positive outcome regarding learning rate, ergonomics and intuitiveness coming from letting the users choose appropriate gestures for certain functions (Wobbrock, Morris and Wilson, 2009; Heydekorn, Frisch and Dachselt, 2010; Wachs et al., 2011). Such findings are in accordance with the philosophy behind Embodied Interaction, promoting interaction that is based on intersubjectivity and shared meaning within the community of practice, i.e. the potential users of the sign language alphabet, for a more natural user experience. Thus, the designer needs to give the users a chance to express their view on the vocabulary, collecting knowledge about how they think and what their view on gestures has in common. Therefore, a modified version of Nielsen et al.’s (2004) procedure was applied for selecting suitable hand signs for MATImyo, as described below.

To begin with, a pre-selection of multiple alternatives for each letter of the Latin alphabet was made from either existing national sign language alphabets or other manual signing systems relying on the designer’s judgment in her role as expert in human-computer interaction via gestures and sign language. Illustrations of the chosen hand signs were composed as test material\textsuperscript{11} and handed to the test users in an online survey together with links to several video tutorials for national hand alphabets. The video tutorials were supposed to give inexperienced participants an idea about how fingerspelling in general and particular signs look like when applied as opposed to the static and sometimes insufficient illustrations.

Ten participants were asked to rate each hand sign’s compliance with four categories on a scale from 1 to 5 with regard to the Latin letter it is to represent. These categories are:

**Ergonomics:**
This category considers the physical aspects of executing the sign of a certain letter, whether it is easy to perform or maintain a certain hand posture and how that feels in the body. A low value would indicate that the sign is hard to execute or even hurts. A high value is assigned if the letter feels comfortable to perform.

**Latin alphabet:**
This category stands for the similarity of a certain sign language letter with the corresponding representation in the Latin alphabet. A low value indicates no or only a little similarity between the two representations of the letter and a high value would be assigned, if the representations were much alike.

**Mouth shape:**
This category considers the similarity between the hand sign of a certain letter and the shape the mouth is forming when pronouncing the letter (concerning shape and

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\textsuperscript{10} See section 3.3
\textsuperscript{11} See Figures 3-5 in Appendix 1
positioning of the lips, teeth and tongue). A low value indicates no similarity, while a high one indicates high similarity.

**Other resemblance:**
This category considers all other associations a user can have with the sign language representation of a certain letter. For example, onomatopoetic aspects (the sign looks like the letter sounds) or the sign looks like an object that is closely associate with the letter (e.g. the “golden M” of McDonald’s reminds of hamburgers and the sign for “M” has resemblance with a hamburger), or anything else that makes a user somehow understand why the sign for the letter looks like it does, previously not covered by the categories above.

Additionally, participants had the opportunity to add information, e.g. what kind of associations they had with the manual representation of a letter or if they had issues along the survey. Furthermore, they were welcomed to make suggestions for alternative gestures. Finally, every participant had to intuitively pick their favorite hand sign out of the alternatives for a certain letter, and were asked to specify the category that was most significant for their decision.

The data derived from the survey was analyzed by the designer. For the quantitative data, the means of the ratings for each alternative in each category across all participants were calculated, which were used for determining the “winners” with respect to different aspects, such as highest overall score, user’s favorites, highest value of embodiment and more.

From the qualitative data, new signs were derived and insight into the users’ meaning making mechanism was gained. The by far strongest motivation for choosing one sign over another was its similarity with the Latin alphabet. But also some interesting associations with mostly objects or cultural gestures were found. Ergonomics seemed to be a basic requirement, but was rather used to rule out certain signs than to pick a particular one.

**4.4 Definition of the final hand alphabet**
Based on the results from the selection process and the design criteria, a final version of the manual alphabet was determined by the designer. In order to achieve this, many compromises had to be made. The users’ choice, while highly weighted, was not automatically accepted for the final alphabet, since they only reflect the user-centered aspects of the equation. Additionally, as Wobbrock, Morris and Wilson pointed out in their study (2009), even though the test users together found more gestures than the three experts, the experts had found hand shapes that were never brought up by the users. Heydekorn, Frisch and Dachselt (2010) concluded that the designer as expert needs to have the last word about the resulting gesture vocabulary in order to evaluate across the whole design space instead of limiting possible solutions to the findings of the test users. Following this advice, a lot of effort was put into finding a combination with the highest possible scores in the categories “Embodied Interaction”, “users’ choice” and “distinctiveness” with Stern, Wachs and Edan’s (2008) methodology for solving the multiobjective decision problem in mind. Some new

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12 See Figures 6-7 in Appendix 2
signs were added, either derived from user suggestions in the survey, or were invented out of the need to find a hand shape that is not ambiguous. Several other signs were modified or used for another letter instead. Additionally, gestures for basic punctuation marks and text editing were developed, mainly with the purpose of providing an authentic functionality for a future user test.

Figure 1 shows the final result for MATImyo. A more detailed overview of the alphabet including a front and a rear view of the hand signs can be found in Appendix 3.

![Figure 1: The final result showing the chosen hand signs for MATImyo. A, B, F and H are new signs elicited from the user testing or added by the designer. Y, P and U are originally used for other letters in the corresponding national sign language, but were found to fit better for the current configuration.](image)

### 4.5 Discussion

Conducting several smaller pre-studies in order to get acquainted with a new research area, appeared to be very useful. The quantitative survey study via Facebook provided for a larger scope regarding the background of the participants, which not only broadens the spectrum of potential results outside the familiar socio-cultural perspective, but also gives the study more validity and an enhanced ground for generalizations. An additional advantage of recruiting participants using Facebook unobtrusively is that those who join the study do so willingly, increasing the probability of high-quality answers. When contacting potential participants

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13 See Figure 12 in Appendix 3
personally, they can feel forced to take part in the study by social rules of politeness, which is likely to lead to a lack of commitment.

Deriving the information for developing a suitable sign language alphabet directly from potential users supported the design process immensely. Similarly, the interviews with the experts in Swedish Sign Language opened the eyes for possibilities and drawbacks of such an interaction style that only can be revealed by practitioners who have extensive experience with it on a daily basis. Moreover, the study of diverse national sign languages, meaning the actual physical execution and cognitive processing of basic signs, confirmed theses aspects. Moreover, it made the linguistics behind the languages clearer and also established tacit knowledge with regard to sign language, which could be applied throughout the design process.

In terms of the design criteria, some suggestions were not followed. MATImyo is not developed for stenographic usage, since it was suspected that such an approach would require the test users to put a lot more effort on learning the vocabulary. Being new to the concept of gestural writing, they might be overwhelmed enough with a hand alphabet that resembles the concept of writing they know. Furthermore, though it was determined that gestures involving motion or more than one hand are excluded from consideration, there were several of such signs included in the pre-selection. This decision is partly based on the fact that some of these particular gestures had a high value of embodiment in the eyes of the designer. To another part, the studies of Wobbrock, Morris and Wilson (2009) and Vatavu (2012) in particular revealed that test users preferred dynamic gestures, mid-air writing and body references. If it had turned out that in the case of an alphabet, such gestures were also dominating the users’ choices, then maybe this design criterion would have needed to be adapted and the application scenario altered in favor of the users’ requirements. However, having such signs included in the pre-selection might have influenced the final result, since users voted for these hand shapes. It is unsure, how the result would have looked like, if those votes were distributed to the more relevant signs instead. Other bias could have come from having the designer compose the pre-selection. This determines from the beginning which types of signs are to be considered by the users and, thus, limits the outcome of the selection process to the perspective of the designer. On the other hand, the designer as expert is trained to explore the whole design space and the users were additionally allowed to suggest alternative signs. However, it is still recommended for a future approach that the whole design process is accomplished with users and designer tightly cooperating in the spirit of true participatory design. Moreover, several alternatives of gestures elicited by the users for one and the same letter should be integrated in the vocabulary for increasing “guessability”, as suggested by Wobbrock, Morris and Wilson, (2009).

It is left to evaluate, if MATImyo meets the design criteria. This is determined in the following user tests.
5. Assessing the user experience of gesture-controlled writing with a manual alphabet

The main focus of this Master thesis lies on assessing the potential and limitations of MATImyo as input language and on the user experience of composing electronic texts with a manual alphabet and a myoelectric gesture recognition device. For this purpose, it is necessary to find answers to the following questions:

- How easy is it to learn and apply MATImyo?
- Which general aspects of MATImyo are perceived positively or negatively?
- In particular, which letters of the MATImyo alphabet need to be improved or replaced?
- Does MATImyo comply with the specified design criteria, especially the criterion of fitting within Embodied Interaction for an improved user experience?
- How does it feel to compose texts with gesture-controlled writing input using a myoelectric device in an authentic scenario?
- Is this kind of interaction style something that users would want to have for accomplishing their everyday computer tasks?

In order to find answers to these questions, user tests applying MATImyo in an authentic use scenario were conducted. In this section, the procedure and methods of the user testing are described and the results are presented.

5.1 Preparations

For teaching the test users how to use MATImyo, some learning material was created. It consisted of 1) a “cheat sheet”\(^ {14} \) with illustrations of hand signs, 2) a tutorial\(^ {15} \) with pictures of the different hand signs as seen from the user’s own perspective, as well as from a conversation partner’s, and 3) a video tutorial, showing the different hand signs in motion and for two different cases: one time, the signs were shown as if the user was interacting with a human conversation partner or a vision-based gesture recognition system; the second time, the demonstrator pretended to use a myoelectric device in a more relaxed position, not having to deal with orientation and visibility issues of the hand shape. Furthermore, appropriate texts\(^ {16} \) that were considered simple enough to remember were chosen as content of the test scenario.

It is crucial to understand, that one part of this study aims at finding out about the actual user experience of the interaction style per se. It is not about the qualities of a certain technology and, thus, technical problems need to be ignored for the purpose of this study. Therefore, the test users are supposed to be under the impression of actually accomplishing an everyday computer task with MATImyo, as previously described in the application scenario in section 1.1. Otherwise, the test users would not be evaluating the full potential of this interaction style as it might be in the future, being distracted by unsatisfying performances of the involved technologies or by misleading test conditions. For this reason, a

\(^{14}\) See Figure 8 in Appendix 2

\(^{15}\) See Figures 9-12 in Appendix 3

\(^{16}\) See Appendix 4
Wizard of Oz experiment was prepared, allowing the researcher to simulate a fully functional system within a test scenario (Martin and Hanington, 2012, p. 204).

![Diagram of the evaluation process]

**Figure 2: An overview of the applied methods in the evaluation process.**

In order to eliminate technological problems with current gesture recognition devices, a test software was developed with Javascript and HTML that enables the experimenter to compensate for missing or unsatisfying functionalities of the test equipment, while the user is interacting with the computer. The experimenter simply has to hit an arbitrary key on the keyboard, which triggers the next sign of the text to appear on the screen. This is supposed to make the test users feel as if the computer actually understands their gestural input. However, the goal of simulating a genuine application scenario was not fully achieved, since some features of a typical writing editor were not incorporated in the test software, e.g. the cursor was not visible and no backspace function was available. Furthermore, no feedback for incorrect input gestures was provided by the system. With a correct input, the system proceeded in displaying the new letter attached to the already entered text. Otherwise nothing happens.

The required technologies consisting of the MYO armband and a large 27-inch display for the actual test scenario as well as a tablet computer and a smartphone for video and voice recording, were tested and prepared. Appropriate furniture for the participants to choose from for their preferred working position were brought in place, e.g. an office chair, an armchair and some floor pillows.
In order to help the participants to understand what gesture-based interaction for everyday tasks can look like, some commercial and informative videos of product developers and research projects were picked to be presented to the test users before the actual test. Those videos were created in a way that they sell the future idea of gesture-based interaction beyond technological issues, making it easier for potential users to understand what the product or project is meant to achieve. For this user test, the videos also served the purpose to wipe out some of the skepticism about the technological realizability.

Finally, suitable test users were selected and contacted.

### 5.2 Participants

<table>
<thead>
<tr>
<th>Name (altered), gender, age</th>
<th>Cultural background</th>
<th>Profession and Interests</th>
<th>Experiences with gesture-based technology</th>
<th>Experienced in using sign language</th>
<th>Alphabets (primary first)</th>
<th>Other information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carol, F, 33</td>
<td>Swedish</td>
<td>CS, IxD</td>
<td>Eye Toy, Dancing Pad (XBox), organ with facial expressions</td>
<td>Yes (Swedish)</td>
<td>Latin</td>
<td>--</td>
</tr>
<tr>
<td>Cordelia, F, 26</td>
<td>Oceanic</td>
<td>IT Management, Gaming</td>
<td>XBox Kinect, Wii</td>
<td>Yes (Australian)</td>
<td>Latin, Japanese</td>
<td>--</td>
</tr>
<tr>
<td>Eva, F, 28</td>
<td>Romanian</td>
<td>Human Resources</td>
<td>--</td>
<td>Yes (Rumanian)</td>
<td>Latin, Greek (theoretically)</td>
<td>Focus issues</td>
</tr>
<tr>
<td>Jenny, F, 24</td>
<td>Polish</td>
<td>IXD, Design, HCI, Gaming</td>
<td>Wii, Xbox Kinect, PS3</td>
<td>No</td>
<td>Latin, Japanese</td>
<td>Gamer</td>
</tr>
<tr>
<td>Matthew, M, 33</td>
<td>German</td>
<td>CS</td>
<td>Kinect, Leap</td>
<td>No</td>
<td>Latin, a little bit of Greek</td>
<td>Technically minded and concerned with social rules</td>
</tr>
<tr>
<td>Peter, M, 45</td>
<td>Swedish</td>
<td>Printer</td>
<td>--</td>
<td>Yes (Swedish, Finnish, International, American)</td>
<td>Latin</td>
<td>Deaf</td>
</tr>
<tr>
<td>Simon, M, 33</td>
<td>German</td>
<td>CS, Support</td>
<td>MYO, Leap, Wii</td>
<td>No</td>
<td>Latin</td>
<td>Pilot Study</td>
</tr>
<tr>
<td>Violet, F, 29</td>
<td>Greek</td>
<td>HCI</td>
<td>--</td>
<td>No</td>
<td>Greek, Latin</td>
<td>Dyslexic</td>
</tr>
</tbody>
</table>

Table 1: An overview of the subjects participating in the user testing of MATImyo.

The participants of the study were chosen because of their diverse backgrounds in terms of origin, experience with sign language and gesture-based interaction, as well as their stances towards technology and languages, in order to cover as many aspects as possible significant for this study. Seven of them were already known to the conductor. Those were invited to the study personally. Only one participant, Peter, was a stranger prior to the study and recruited via the local association of the deaf. He is deaf, but has learned to articulate himself in Swedish and can read from the lips, so there was no need for involving a translator. Peter is a
full-time practitioner of Swedish sign language and also Carol and Cordelia had previously come in contact with sign language through deaf colleagues.

The majority of the participants were between 24 and 33 years old, except from Peter who was 45. Three of the participants were male, five were female, all were right-handed. One participant, Violet was dyslexic, having problems with spelling and writing tasks in general. Furthermore, she stated that the Greek alphabet was her first alphabet, and Cordelia and Jenny had learned the Japanese alphabet at school or for private reasons. While all participants were currently living in the same town, the preferred language for the experiment and interviews depended on the subjects’ origin: four participants chose English, two Swedish and another two German as language for the user testing. All participants except from Peter have an academic background and six of them are working or studying within technology-related areas (e.g. computer science, IT management, human-computer interaction or interaction design). Simon is working as user support and software developer at a university department and, thus, can be seen as an expert on typical issues of common computer users. Throughout this work, the names of the participants have been changed granting them anonymity.

5.3 Applied methods and procedure

For gaining an in-depth understanding of potential users’ issues with MATImyo and gesture-based writing input, methods for qualitative data gathering and analysis were chosen. Eight user tests consisting of a “Wizard of Oz”-style experiment (Martin and Hanington, 2012, p. 204) and accompanying interviews before and after the test were conducted. An interview style based on the general interview guide approach and the standardized open-ended interview approach (Turner, 2010) was applied, enabling the researcher to adapt to the current interview situation (the interview guide can be found in Appendix 5). The first user test with Simon served as pilot study in order to optimize the procedure for the following participants (van Teijlingen and Hundley, 2001). However, the results from the pilot study were regarded equally relevant for the study and, thus, were analyzed and included in the final result. The analysis of the results was conceptually based on thematic analysis (Braun and Clarke, 2006) and the affinity diagram approach (Martin and Hanington, 2012, p. 13).

Prior to the user test period, the participants were provided with the test material and asked to memorize the manual alphabet, as well as to practice each text with MATImyo at least once. The actual user tests were then conducted on different occasions with one participant at a time. In order to raise the participants’ motivation and to create a trustful atmosphere, the participants were in advance briefly informed about the purpose of the study and the protection of their anonymity by the conductor. Furthermore, technical details about the test circumstances were addressed and the subjects notified that the test actually is a “Wizard of Oz”-style experiment, but should be treated as if dealing with working technology. This was initially not planned, but turned out to be necessary after the pilot study with Simon, because of the technical constraints of the test software that were mentioned before. The imperfection of the test equipment contributed more to a negative user experience than potential skepticism about the reliability of the technology.
Before engaging in the practical test, the subjects were interviewed about their experiences with sign language and gesture-based interaction, as well as other relevant aspects about their background. A lot of focus was put on their prejudices against and expectations of using sign language both towards other humans and as a way of interacting with the computer. It was considered useful to catch prejudices and expectations concerning gesture-based interaction before the actual test in order to better understand the user experience, since it was suspected that there is a possibility that negative encounters with gesture-based interaction in the past could downgrade the whole experience.

After the initial interview, the participants were presented with the demonstration videos about gesture-based interaction for everyday tasks and sign language translation. The future scenario describing how MATImyo can be integrated in a multimodal interface, as presented in section 1.1, was introduced. The subjects were informed about MYO's properties providing for the users to be able to both do the signing a bit sloppy without thoughts about the right orientation of the hand or its visibility, and to choose any comfortable position within a range of about 5 m from the screen in order for the experimenter to have a clear view on the test users, while operating the test software at the desk. Most of the users chose to sit in an armchair in a relaxed position about 3 m from the large screen. Even though the MYO armband was not functioning in this Wizard of Oz test, the participants were asked to put it on, in order to make the test situation more authentic. They were then told to “write” the prepared texts by using MATImyo, while the experimenter operated the test software. For keeping the test situation as realistic as possible, the test users were provided a cheat sheet with pictures of the alphabet, since they would also be able to look up the alphabet in a real use situation.

Immediately after the Wizard of Oz experiment, a second interview was conducted with the question about the hedonic qualities of the interaction with MATImyo prompted only seconds after the actual experience. It was considered crucial to catch the user experience without giving the user the time to reflect on it, in order to gain insight into the unaltered user experience of using MATImyo in particular, and the interaction style in general. The participants were also asked about their opinion about MATImyo as gestural input language, what should be improved about the alphabet or which aspects were considered helpful and positive for accomplishing the task of writing a text with myoelectric gesture recognition devices.

The whole procedure of one user test took about 2 hours, with the two interviews (before and after the experiment) together lasting between 40 and 90 minutes and the Wizard of Oz experiment about 10 to 20 minutes. The interviews were voice recorded, while the experiment was video recorded for further analysis.

Some alterations were made to the repertoire of questions depending on different conditions with particular participants. As some of the test subjects were volunteering to give deeper insight into further aspects related to the core questions of the interviews, some additional questions were posed to them. Contrary, two users had only limited time for the user testing and Peter had from time to time problems to understand the questions or to articulate himself. Thus, they were presented with a subset of the questions that covered the most significant aspects, assuring a good quality of the data for the study.
The analysis of the data was initiated by transcribing the recorded interviews in their original language as a first step to gain deeper understanding of the interviewees’ statements, which facilitated the pattern-finding process. Thanks to the small scale of the study and the well-structured interview guide, the transcriptions could be manually categorized. With thematic analysis and the affinity diagram as inspirational sources, the results could be derived both inductively and deductively: similar statements were summarized and abstracted into themes, in part with regard to certain pre-defined aspects relevant for this study. Additionally, the video material was examined in order to reveal the actual performance of the test users, as well as hints about the user experience expressed through body language. Out of these two analytical steps, various insights about the user experience of gesture-controlled writing input in general and with MATImyo in particular were won. The results are presented in section 6.

5.4 Limitations of the study
Since this study is very limited in scale with only eight participants, who additionally were quite homogenous with respect to their age, place of residence and involvement with technology, it is not recommended to derive global generalizations from its results. In another group of test users with different socio-cultural backgrounds, norms, alphabets and stances towards technology, other reactions towards this new technological development might occur. Thus, the results of the study are most of all to be seen as inspiration and starting point for further examinations about the user experience of gesture-controlled writing input.

Furthermore, it is very likely that the circumstances of the test situation with shortcomings in the test software and a non-working MYO armband contributed to a negative effect on the user experience. It is questionable, if the achieved results actually reflect the exact user experience of such an interaction style with a fully functional system. Some users also mentioned that they felt nervous about their performance, which led to them focusing most of all on doing well, instead of just accomplishing a task.

The result could also have been affected by the positive feeling users got from trying out something new and futuristic. On the other hand, since all the participants were novices at using MATImyo and experiencing cognitive and physical problems typical for beginners. Therefore, this study can only hint about the user experience of someone who has great experience with both this particular sign language and the technology. Similarly, MATImyo’s developmental status as prototype might have led to a different result than an optimized version would have.

Furthermore, the acquaintanceship between the interviewer and most of the participants, didn’t appear to have noticeable effect on the results. However, the interviewer’s knowledge about the subjects influenced how their answers were interpreted and also determined, whether the interviewer was able to understand the statements of the subjects as they were, without further explanations. It is possible that another person reading the transcribed interviews might get another impression about how the data could be interpreted than what has been presented in this study.
6. Results

From the interviews and the user testing with the Wizard of Oz experiment, the following findings were collected concerning the participants’ previous opinions about gesture-based interaction, the user experience of using gesture-controlled interaction in general and with MATImyo in particular, issues with MATImyo as input language and the test users’ comparing view on the standard interface and gesture-based interaction. It is to mention that quotations from interviews in other languages than English were translated into English throughout this work.

6.1 Prejudices against gesture-based interaction

When asked, what could be reasons to not choose gesture-based interaction, or what could be issues with this interaction style, the participants came up with a variety of potential aspects. The most prominent concern the participants had about gesture-based interaction referred to physical issues. Six of the eight test subjects believed that this kind of interaction would either lead to pain in arms, hands and fingers after a while or would be just too exhausting to be applied for extensive tasks. Similarly, the additional cognitive load that a sign language might put on the user was questioned. There were also prejudices against the social appropriateness of gesture interaction among three of the test subjects regarding the application at work or among strangers who are not familiar with such an interaction style leading to confusion. They were afraid that in conservative companies or certain countries, such an interaction style could be perceived as an unserious, ridiculous-looking fashion and even scare off customers. Thus, the majority of test subjects agreed that the boss of the company would need to initiate and support the introduction of such a technology at the workplace and only three believed that an employee could just adopt this interaction style at work without talking to the boss first. Two participants saw a problem in people’s aversion against replacing a working solution, as the keyboard, with something new, in which they would have to invest time and effort in order to learn its usage properly, most of all when it is unclear, if this new input style actually works as efficient as the one they already mastered. Other issues with gesture-based interaction concerned privacy and secrecy risks, when people can read from the hands what the user is writing, as well as technical problems with the accuracy of the gesture recognition technology or appropriate feedback about the correctness of the gestures and the actual spatial range for gesture recognition. Those aspects were only mentioned by one participant each.

The test subjects saw adoption problems with this kind of interaction not only for people who are for physical reasons unable to use their hands properly, for example people with certain physical disabilities or those who are executing manual labor, but also because of certain character traits or lifestyles. They named insecurity, shyness and conservative, reactionary mentality as examples character traits with people who might reject such an unusual interaction style. It was also pointed out that elderly in general are believed to have problems with changes and learning new techniques and routines. Three of the participants found it very likely that users who consider themselves as experts in computer-related matters (e.g. gamers or software developers), might refuse to adopt another interaction style for socio-cultural reasons. It was mentioned several times, that gamers have a tendency to
express their affiliation with this socio-cultural group by exclusively using and worshipping a certain set of equipment, mostly keyboard and mouse. They added, however, that if the technical issues of gesture-based interaction were solved and some kind of “idol” in this branch would introduce it to the gamers, then they would certainly follow the example. In a similar way as the gamers regard their choice of equipment as an expression of their culture, the applied computer sign language could pose a threat to the historical and cultural meaning of sign language for the practitioners of the official national sign languages, as the deaf participant, Peter, pointed out.

6.2 The user experience of using MATImyo and gesture-controlled interaction in general

Seven of the test users experienced gesture interaction for text input as generally positive. Only one user, Matthew had a rather negative feeling about this interaction style, which was based on the fact that he was a novice in MATImyo and struggled with the cognitive load and suffered from exhausted muscles in arms and hands, as he stated.

“On the one hand, it was fascinating that you actually can write with it, I mean certain combinations worked relatively quickly. On the other hand, quite exhausting, most of all, because I’m new to this. [...] It was interesting, but I was kind of glad when it was over.” (Matthew)

He questioned, if it would be worth to go through all this when he still could use the keyboard, which he considers sufficient for the task of writing texts in spite of its flaws. Jenny expressed similar thoughts, making the transition to any new interaction style a matter of motivation. However, she and all of the other participants, except from Matthew, described an overall positive experience, ranging from “natural and comfortable enough” (Jenny) and “It worked well. [...] The computer did what it was meant to do.” (Carol) to “It feels enlightening [...] it was very freeing and maybe sort of liberating from the keyboard.” (Cordelia). This feeling of naturalness and liberation was shared with two other participants. Furthermore, Simon felt proud and successful after the user test and Carol stated that “it was amazing to test”. Peter was, on one hand, very pleased by the interaction style itself, as it is in line with the way deaf are communicating most of the time. He referred to sign language as “his language” as opposed to the verbal or written language and pointed out that “it was totally wonderful” to communicate with the computer with sign language. On the other hand, Peter got often frustrated about hand shapes in MATImyo that were used for other letters in his sign language alphabet, e.g. the MATImyo sign for “D” is the sign for “E” in Swedish Sign Language. He felt cognitively exhausted because of that, even though the hand shapes were familiar and physically no problem to execute. Frustration was also felt with other participants, mostly when they compared their writing efficiency with their performance on the keyboard, or when they struggled with personal issues like dyslexia or concentration deficit. At the same time, five of the test subjects stated that their muscle memory had already worked, which allowed for thinking ahead and supported the spelling process with seemingly automatic transitions between the hand signs. For the dyslexic Violet, this was a major advantage, since she “only had to remember the hand shape, nothing more”. While
Carol still believed that she “might get too exhausted after a while”, most of the other test users were quite satisfied with the low cognitive load, which Simon perceived as much lower than with the keyboard in the beginning. He also mentioned, that “writing” with sign language was “more comfortable than sitting in front of the computer”. In terms of physical aspects of the user experience, being able to choose a comfortable working position was very much appreciated, even though none of the users actually remained in the initial position with relaxed arms and shoulders as soon as the test started. Some of them explained that they intended to sign the letters with resting hands, but their arms automatically went up as if communicating with a human. This was perceived as exhausting after a while. Other physical issues concerned untrained finger muscles and mostly the execution of the MATImyo sign for “H”, which put a lot of strain on the muscles and tendons and was almost painful for two users.

Of the eight test users, only two were doubtful if they would wish to continue with such an interaction style for their everyday computer tasks. Their explanation was the lack of motivation, meaning that they were satisfied with their performance on the keyboard and did not need an alternative. While three participants would want to choose gesture-based interaction most of all for certain applications, for example mobile tasks or writing short messages and posts, three subjects stated that they would gladly get rid of the keyboard and adopt this new interaction style for usage on a daily basis.

“I would totally leave the keyboard for this!” (Eva)

“[…] I would definitely engage in it on a daily basis, it would become adopted into my lifestyle and my daily practices.” (Cordelia)

Peter explained his motivation from a deaf person’s point of view:

“If I could choose, yes, absolutely! Then I would be able to get rid of the keyboard […] because it is used in another language than I would like to have. […] I don’t have to force myself to adjust to some norms and rules with [sign language input].”

6.3 Aspects about MATImyo
The subjects were asked about their opinion about MATImyo as gestural input language for composing digital texts. The results from their answers are presented in categories below.

6.3.1 General impressions about MATImyo
The feedback about MATImyo from the test users was for the most part very positive. Without exception, it was found to be easy to both learn and apply.

“It was very well optimized and easy to memorize. I didn’t expect it to be memorized that fast.” (Jenny)

Also on an ergonomic level, MATImyo was overall perceived as being “natural” and no problem to execute physically.
“...the transitions are a very important part of sign language. There is a lot of fluidity with most of your characters. ...The “R” and the “S” slide really nicely, because you have a lot of cases where you have like “R-S”, it’s a very easy transitional letter.” (Cordelia)

The fact that MATImyo represents letters instead of whole words, was found to be both positive and negative. Several test users agreed on the facts that they, firstly, would need to learn far more signs with a word-based sign language than simply the ones for the alphabet, and secondly, that they were much more free to express what ever word they needed with a letter-based signing system. However, with regard to efficiency, they would prefer a word-based version. Especially Peter who is used to signing on a one-sign-per-word basis, was frustrated by the slow pace of expressing himself with a letter-based communication. It was also he, who encountered reasonable problems with divergent meanings of hand shapes that are part of both MATImyo and the Swedish Sign Language.

6.3.2 Memorizing the alphabet

In average, the test users invested 27.5 minutes for memorizing the alphabet. Four of the eight subjects needed even less than 15 minutes and two others less than 30 minutes. For the two remaining, it took 45 and 60 minutes to learn MATImyo to the extent where they could express any letter of the manual alphabet without peeking on the “cheat sheet”. It was explained that the similarity of the hand shapes with the corresponding letter of the Latin alphabet (e.g. “W”, “V”, “L” and “A”) was the most powerful source for memorizing MATImyo that quickly, since most of the letters were “very obvious”. Other prominent aspects that helped the participants in learning MATImyo was the knowledge of some other sign language, because the hand shapes were familiar and in many cases also represented the same letter (e.g. “M” and “N” from American Sign Language), as well as associations they had with objects that start on the respective letter and that looked like the hand shape (e.g. “T” as in “telephone” or “R” as in “revolver”). Similarly, participants related personal experiences with certain hand shapes:

“[...] my mother’s name is Kyla and the ‘K’, whenever she goes to whistle, she goes like this [shows how her mother would whistle with her fingers, which are almost forming the MATImyo sign for ‘K’].” (Cordelia)

“I think [the ‘S’ is] actually quite cute. [...] today, [Matthew] ‘wrote’ me ‘puss’ in Swedish and when he actually did this, it actually looked like a kiss. [...] when [Matthew] ‘told’ me today ‘kiss’, or ‘puss’ in Swedish, it really felt like an ‘S’. Like when he was doing it, I understood it without actually thinking about the word. So it felt actually like a kiss only from the gesture.” (Eva)

Furthermore, subjects stated that they remembered hand shapes because they “were funny, like the rabbit [for ‘Y’]” or, in Peter’s case, because they mean something else in Swedish Sign Language, which he then associates with the letter, e.g. the MATImyo sign for “A” is the Swedish sign for “rack”. Only two participants were mainly just memorizing the combination of hand shape and corresponding letter by heart without further associations, while exploiting the muscle memory for cognitive support. Another test user found it helpful that
the transition from “M” to “N” in MATImyo is like counting backwards with the fingers from three to two.

### 6.3.3 Issues about hand signs or sign combinations

Not all letter representations in MATImyo were without troubles. Most of all ergonomic aspects about certain letters were subject of critique. While “F” and “P” were found to be hard to perform for a few test users, the “H” was the main point of critique for all of the users, even causing pain in some users’ hands. This hand shape was the most prominent reason, why participants had problems with their performance in general, causing both physical and mental exhaustion and limiting the application duration, as they stated. It was found that “H” is a very important letter in English and, thus, needs to be formed in a way that frequent words containing an “H”, like “the”, can be performed equally simple and quickly as shaking the hand. The same was said about the sign for “E”. Additionally, “E” and “F” were suggested to resemble the way Americans count with their fingers, thus, these hand shapes were supposed to be composed using index, middle and ring finger instead of middle, ring and pinky finger.

The sign for “A” was violating the participants’ mental model about MATImyo based on the majority of its hand shapes. It was perceived as derived from another language system and disrupted the “writing” flow, even though the participants agreed that the hand shape for this letter was very well designed in general. Similarly, the representation of the letters “D” and “G” in MATImyo suggested that the sign for “P” would be like the sign for “Q”, which led to initial confusion. Other hand signs that are based on associations rather than the shape of the Latin letter (e.g. “R” and “S”), were not understandable for all subjects to the same extent. Some needed to be explained to become clear, but some were still simply going against the subjects’ mental model. Moreover, Violet had problems with the similarity of certain hand shapes, like the MATImyo signs for “D” and “G”, because of her dyslexia and Cordelia pointed out that she felt a little bit uncomfortable with performing the sign for “P” with the extended middle finger for cultural reasons.

### 6.3.4 MATImyo’s compliance with Embodied Interaction

Six of the participants were introduced to the concept of Embodied Interaction and asked if they experienced MATImyo as embodied. All of them agreed that aside from being an interaction form that is performed by using parts of the body, it is also meaningful for and between individuals regarding the similarity of the signs with the Latin letters or natural associations user’s had with hand shapes and their corresponding letters. The participants decided further that this would maybe not be true in other parts of the world, where people are using another alphabet, but could see how most of the computer users are familiar with the Latin alphabet anyway.

### 6.4 Comparing gesture-based interaction with the standard interface

The participants were asked to compare their experiences with the standard interface to those with gesture-based interaction. In order to determine, how far they have come in learning to write via those interfaces, they were presented with a scaling system from 1-100%,
where 100% represents the maximum level of capability to make text input in a very high speed and without any errors. The absolute best case for a human operator, in other words. For typing on the keyboard, four users saw their writing skills around 40-60%, the other four between 70 and 90%. For using MATImyo, Peter saw himself at a performance level of over 70%. Further, writing skills with MATImyo were estimated to be around 10% by the two other male subjects, 30-40% by two of the female participants and 50-60% by the other two female test users. It is to mention that two of the female participants found their writing skills with MATImyo 10-20% higher than with the keyboard, even though they have used the keyboard for 20 years or longer.

In terms of the learning curve, all seven participants who were able to answer this question agreed that it was faster to learn MATImyo than learning to write on the keyboard. The majority also found it easier to learn.

When comparing the two interaction styles regarding more practical aspects, participants mentioned as strongest advantage of gesture-based interaction over the standard interface, that the user is liberated from the desk and free to choose a comfortable working position. It was considered a “necessary evil” (Matthew) or “a compromise for now” (Violet) to have keyboard and mouse as standard interface, since it was perceived an unnatural interaction style for a human that also binds the user to the desk in an uncomfortable position while working. This was assumed to lead to sedentary behavior with all its physiological consequences and other physical issues. Gesture-based interaction, in contrast, was believed to counteract those issues in spite of putting strain on the hands instead. Being freed from stationary input equipment pleased the test subjects, who saw great potential for mobile usage on the go or “lazy” computer interaction from the couch. Since you always have your hands with you, Eva pointed out that she would be able to learn this interaction style faster, since she would not need to get access to any equipment during the learning phase, but could practice the hand shapes whenever and wherever; even with human communication partner, who she could share this sign language for normal communication with.

When learning about the fact that even toddlers from an early age as 8 months can express themselves through basic gestures, several participants suggested that having a universal sign language from birth that both works with humans around the globe and with computers would help them a lot in everyday life. This would eliminate language barriers between countries and building a bridge to people with speech or hearing disabilities, as well as simply affording an alternative communication channel in places where you cannot speak or hear the communication partner (e.g. over a distance in a noisy room). It was considered a natural way of communication to use gestures and sign language between humans and, thus, also a natural way to interact with computers. Using your body as input medium was assumed to not only make you feel better, but also to make the interface simpler and to humanize the computer. It was supposed that this would make the computer less scary for many people and that the feedback you get from moving your body and the muscle memory support the interaction and work with the computer.

Peter explained that the keyboard can be seen as a bridge to those people with hearing and speech disabilities who have learned the verbal language. But at the same time, it excludes many other deaf, whose natural language is sign language.
When it comes to actually writing texts on the computer, there were different opinions about what would be the ultimate solution in the future, when technical issues are eliminated and the sign language optimized. The majority believed that a word-based sign language would be the most efficient way to enter text. Aside from that, the keyboard was found to work well for now since they spent a lot of time with it. A letter-based sign language, which they only have started to learn, could not compare with potentially hitting eight keys at a time. They felt that using the keyboard was not as physically and mentally tiring as they envision sign language to be and saw benefits from the visual and haptic feedback they got from looking at or hitting the keys. At the same time, it was perceived annoying to have to look at the keys while writing, which leads to errors with data entries. Even more irritation caused the fact that there is no international standard of the key layout across languages or even brands. Also the key size can vary, making it hard to re-use the learned writing skills between devices. All the keys on one device feel the same and the key arrangement seems illogical, making it harder to learn and still causes a lot of typing errors. It also makes it very difficult to use for people with dyslexia, according to Violet. The fact that hitting the keys makes click sounds and that you constantly have to switch between keyboard and mouse, was also seen as a moment of annoyance. In contrast, gesture-controlled writing was considered “cool” (Carol) and “fun” (Jenny), while it is assumed to reduce typing errors with very distinctive gestures as in MATImyo, enables multitasking and prevents you from looking at your hands while entering data, being able to monitor the screen all the time. According to the participants, it not only provides for applications like digital painting and handwriting, as well as for gaming shortcuts that are quickly controlling certain functions like magic spells or using tools and weapons in roll games or shooters, it also “solves a lot of problems” (Violet). Violet stated that a word-based input language would instantly eliminate all the spelling troubles she went through every day and a letter-based sign language would still support her by making use of the muscle memory. Similarly, several participants assumed that learning the Latin alphabet with hand signs might support young children when learning to read and write, since the proprioceptive skills facilitate the expression of a letter through the own hands, instead of having to control a pen. In addition, the muscle memory was suspected to develop stronger with hand signs than with writing. Cordelia sees a possibility for people with speech impediment to finally be able to make use of services based on natural language, like Apple’s Siri.

Also after experiencing gesture-based interaction in a test scenario, issues some test users saw with gesture-based interaction on a socio-cultural level remained. The appropriateness of sign language in work-related contexts was still questioned, because it might look “weird and awkward” (Jenny), not serious or professional enough, and people could read from your hands, leading to secrecy and privacy issues.
7. Discussion

This section aims at providing perspectives for how the results from the main study should be interpreted with respect to the theoretical framework of Embodied Interaction, discussing what they could mean and what we can learn from them. Furthermore, suggestions for future research are given.

7.1 Reflections on the conduction of the study

Combining a video recorded Wizard of Oz experiment and qualitative interviews as research methods was considered being beneficial for compensating for biased data that was derived from one method through the application of the other one. Additionally, the interviews extracted subjective data from the participants, while the analysis of the video material discovered objective data, which later could be compared with each other in order to arrive as close as possible at the actual truth.

7.1.1 Reflections on the Wizard of Oz experiment

Since the current technological solutions for gesture-based interaction are not delivering the necessary reliability yet, a user test based on the Wizard of Oz experiment was compensating for this deficit. Even though the test setup was not flawless and participants were informed about the circumstances of the test, it was to a great extent accomplished to provide the test users a glimpse of a future interaction scenario. Without a genuine use context including a seemingly working system and an authentic environment with comfortable furniture, it would not have been possible to investigate the true user experience. However, some bias derived from the shortcomings of this test setup was discovered. With the participants aware of the system being simulated, skepticism about the technical realizability of such a system could not be eliminated fully. This was very much reflected in the user experience of Matthew, who claimed that he could not overcome his pre-defined negative attitude towards gesture-based interaction based on previous experiences, since he had analyzed the technology and its flaws and assumed that it would not work well enough any time soon. This problem is also described in Nielsen et al. (2004) and following their advice to prevent most of all technically minded people from this kind of thinking through the test scenario is strongly recommended for future approaches. Therefore, aside from taking care of technical issues of the test software, it would have been preferable to have at least one more person in the research team acting as a truly invisible “wizard”, while the other researcher observes and documents important findings during the testing.

7.1.2 Reflections on the interviews

Interviews are suggested to be “the gold standard” (Silverman, 2000, p. 291) when it comes to qualitative research, as they usually supply the researcher with deep insight about the issues to be examined. This became evident in this study, achieved by facing the participants in person and, thus, incorporating the human skill of conversation. It was found that such skills provided the researcher with a richer picture of what has been stated, being able to include body language, intonation of the voice and tacit knowledge about how to read or even feel human emotions. This was certainly amplified by the fact that the interviewer knew most of the participants on a private level and learned earlier how to interpret their way of
expressing themselves. These qualities of the research method were beneficial for such a user-centered study with a big part of the focus lying on understanding intersubjective meaning making mechanisms and emotional aspects of an experience.

By interchanging the standardized open-ended interview approach with the general interview guide approach according to the requirements of the current test situation, their strengths were combined to a powerful instrument for qualitative research. As far as possible, the standardized open-ended interview approach was applied in order to reduce bias by the researcher through open-ended questions (Turner, 2010). However, many test situations required temporary adaptations concerning the arrangement or wording of the questions, resulting in the general interview guide approach. This prevented the conversation flow from being slowed down or even interrupted by awkward placement of questions in relation to the respondent’s preceding answer, while it still guaranteed that all participants got to discuss the same set of core questions (Patton, 2002).

Peter mentioned at one point that he had a hard time to express everything he wanted with the verbal language and was unsure if he understood all the questions the right way. The uncertainty made him feel a bit uncomfortable. In order to meet these specific problems with interviewing deaf participants, the interview questions should be handed to them in advance, so that they can prepare for it. It would also be beneficial to involve a sign language translator for very difficult cases.

7.1.3 Reflections on the analysis
The fact that the gathered data was transcribed and analyzed by the same person, the interviewer, has the advantage, that the analysis procedure is shorter because the data is already known to the analyzer from the interviews and the transcription process. It also reduces the risk of misinterpretations by another researcher as a consequence of the personal style in which the interviews were conducted. A disadvantage is, however, that there was no other party involved to analyze the data unbiasedly. Doing all the work alone might lead to bias, which could be eliminated by having two or more researchers going through the analysis either separately and afterwards comparing the results, or by discussing them from different perspectives.

7.2 The alphabet’s compliance with the design criteria and improvements
Even though the feedback about MATImyo as input language for gesture-controlled writing was overall very positive, the user testing also revealed some aspects that need to be taken care of. At this point, the compliance of MATImyo with the design criteria described in section 4.2 is discussed.

Machine-centered aspects
During the experiment, the conductor noticed that some of the hand shapes were prone to be mistaken for similar ones. This concerns the signs for “Z” and “Y” as well as “D” and “M”. Though there might occur technical problems with accurately distinguishing between these signs with “sloppy” signers, MATImyo is regarded to fulfill the technology-centered design criterion, since it is not clear how far this would be an actual problem with a mature gesture
recognition technology. Nevertheless, those hand signs should be modified in order to eliminate this problem.

**User-centered aspects**

Aside from issues that emerged as typical problems of beginners, MATImyo still needs a few improvements in order to comply with the user-centered design criteria.

From an ergonomic perspective, MATImyo was found to work very well. However, the letters “H”, “E”, “F” and “P” still need to be improved, in order for MATImyo to fully meet the design criterion of being ergonomically friendly.

In terms of efficiency, transitions between frequently succeeding letters need to be optimized, again mostly around the letter “H”, but also the “E”. For the very most frequent words or combinations, even shortcuts could be considered. For example, the article “the” could be represented by shaking the hand while forming the MATImyo “T”. A related thought regards a gesture-based version of stenography, where syllables can be expressed by one sign. This preserves the modular character of MATImyo allowing for unrestricted text generation, while it makes the writing process more efficient.

MATImyo was also found to be culturally acceptable for both practitioners of sign language and mundane gestures, except from the sign for “P”, which was associated with the gesture of “giving someone the finger”. However, this gesture was in no way culturally challenging for the deaf participant, since this is the Swedish sign for “R”, which he is used to. Therefore, it can be assumed that the negative notion of this gesture will disappear with the interaction style spreading throughout our society. The hand shape could be equally accepted as it is for the deaf today.

The “A” and the “P” were perceived as not in compliance with the structure of the language or similar letters in the alphabet, while the rest of the letters were following a common theme and meeting this design requirement.

A more complex design criterion was the compliance with Embodied Interaction. According to the test users, MATImyo is very well situated within this framework based on the fact that the interaction is executed with a body part and meaningful to a community of practice comprising all people who know the Latin alphabet. They also identified other associations with the letters and their representations in MATImyo, like the telephone gesture for “T” and the kiss-like appearance of the MATImyo “S”. But is this enough to classify as “embodied” interaction? Would it be equally embodied to just write the Latin letters in the air and let the technology track the motion? Is it enough that the manual alphabet resembles an abstract construct, the written language, which in turn is a representation for something concrete in the physical world, e.g. a tree, which neither the written nor the verbal expression has anything in common with? Or would it be necessary to find hand shapes that are more associated with the mouth shape or the phonological expression of a letter in order to fit within Embodied Interaction? Those issues are not easy to decide upon. For now, it is enough to argue that the Latin alphabet is for many people such a substantial part of their daily communication that it is to be seen as a natural way of expressing themselves. Besides, Embodied Interaction is not only about the physical component of interaction, but also social interaction. If we suggest that people are using this particular sign language for communicating with each other in the real world, then an
interaction style based on this language is also embodied. With this perspective, MATImyo is also fulfilling this design criterion.

Finally, “guessability” could be increased by including several alternatives for each letter in MATImyo, as was suggested by Wobbrock, Aung, Rothrock and Myers (2005).

### 7.3 A “clean” user experience of gesture-controlled writing

The study succeeded without doubt in shedding some light on the user experience of gesture controlled writing with myoelectric devices. From the reactions of the test users, it became clear that there are issues concerning both the technological solution for reliable gesture recognition and aspects about the interaction style itself that need to be overcome, before the vast majority of people will be motivated enough to give gesture-based interaction a chance as part of their everyday work with the computer. This section discusses to which extent those issues can be neglected and aims at determining the “clean” user experience.

**Skepticism about the enabling technology**

Comparing to how technological developments in other computer-related sectors went, for example the immense progress in natural language processing with speech recognition applications like Siri, it is very likely that also the technology for gesture recognition will get to this point soon.

**Social and cultural rejection**

Social or cultural aspects will probably be wiped out with time, similarly as we could witness after the introduction of cell phones or the acceptance of English as international computer standard, spreading the Latin alphabet around the world.

**Cognitive effort**

Although several participants did mention having cognitive issues for now, which, as they stated, could be explained with the fact that they were new to sign language, it is likely that such problems will disappear when MATImyo is applied on a daily basis. Through practice, the muscle memory is activated and will relieve the user from the cognitive burden even more, as supported by the sign language experts. This will also facilitate the transitions between hand shapes. It was confirmed by the test subjects that it was not at all difficult or tedious to learn MATImyo, it was even perceived easier than learning the keyboard. This might partly be a result of its thoroughly elaborated design with foundation in Embodied Interaction. To another part, it is surely also one of our intrinsic communication skills that lets us learn sign languages and gestures as one of our natural resources for expressing ourselves. Deaf learn sign language without issues as was stated by the sign language experts, and even toddlers can apply it from an early age of only eight months (Bonvillian and Folven, 1987). There is no reason why we should not be able to learn a vocabulary in sign language for interacting with the computer, exactly as we learned to hit the right keys on the keyboard. People are willing to take classes for being able to write on the keyboard properly, so it is reasonable to assume that they would do the same with sign language, if they have a motivation for that. The sign language could then be used in human-human communication as well, an idea that found great acceptance among the test users.
Physical issues
Even physical issues are likely to disappear when MATImyo is used on a daily basis. The muscles and joints will be better trained for the hand and finger movements and the muscle memory will relieve the user from the cognitive burden even more, as confirmed by the sign language experts. With increased confidence as advanced or expert users, they will probably also choose a more flexible and relaxing working position, granting MATImyo to live up to its full potential regarding the distinctiveness of the hand signs for reliable recognition by the technology, while allowing for a healthy posture.

Efficiency
With practice, the muscle memory will support the writer and enable quick transitions between letters. Also, a word-based or stenographic letter-based sign language can increases writing efficiency enormously.

Fatigue
People usually do not write texts longer than a few lines in a row. The writing flow is interrupted by small resting intervals when looking something up or reflecting upon the content or wording. Even a pause of a few seconds is likely to extend the comfortable application duration limitless, when comparing to the statements of the sign language experts about everyday usage of sign language.

Privacy
With a myoelectric device, it is no longer necessary to perform the gestures visible for the technology to recognize, and with this, readable for others. This is one of the major advantages of this kind of technology, as pointed out by (Costanza et al., 2004).

The discussion shows that most of the current issues with gesture-controlled writing will probably decrease or even be eliminated with time. There is no doubt that this kind of interaction has the potential to become a part of our everyday life and integrated in our daily computer applications as human-friendly interaction alternative. So, how would the actual user experience be? Regarding the remaining remarks about the user experience in the study, it seems to be an overwhelmingly positive experience marked by the joy of being able to interact with the computer through the body and the liberation from the desk. This is in accordance with the previously described findings in related research about the user experience of gesture-based interaction17.

7.4 Implications of the results
The results from the study give implications for designers and developers of gesture-based interfaces, as well as for researchers dealing with meaning-making mechanisms and natural gestures for human-computer interaction.

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17 See section 3.2
7.4.1 Implications for designers and developers
As was mentioned before, the overall user experience of composing electronic texts through gestures was positive, even though users had at the same time encountered usability problems. What we could derive from that is the fact that the positive impressions ruled out the negative ones. The positive impressions were related to joy, for being able to both choose a comfortable position and operate through the body, and the sensation of a novel experience. In a sense, one could conclude, that the positive elements of the user experience increase the overall satisfaction of the interaction experience in much the same way as Tractinsky (1997) discovered that aesthetic design increases the perceived usability of a system. Taking both these observations into account, the implications can be derived that “beautiful works better and fun is worth the effort”. Designers are thus advised to emphasize hedonic qualities of an interactive system in order to convey a positive user experience.

Furthermore, the MATImyo representation of the letter “A” was perceived as not belonging to the same design language and lead to confusion, even though the hand shape itself was considered both meaningful and easy to perform. We can conclude from this, that the overall mental model of a gesture language has a greater impact on the perceived usability than was expected, which is also supported by the users’ statements about the misleading assumption that from the cohesiveness of “D”, “G”, the “P” would look like the current MATImyo “Q”, even though those were considered to be of the same design language, but mixed up. Further research is necessary in order to understand the relationship between embodied gestures (as the “A” certainly can be considered to be) and a cohesive design language. At this point, the findings of this study imply that a cohesive design language is to be prioritized before the meaningful design of a single sign, since the mental model of the gesture language as a whole provides the necessary understandings from which meaning for the individual letters can be derived. Designers are therefore recommended to give more weight to the design criterion of a cohesive design language in order to not confuse the user. This is a common insight in other parts of interactive system design (Benyon, 2010) that can now be confirmed for gesture vocabulary design as well.

7.4.2 Implications for researchers
It was previously mentioned that Grandhi, Joue and Mittelberg (2011) investigated natural gestures in mouse-related tasks. This work expands their contribution to the context of composing texts using gestures as a replacement for the keyboard. While Grandhi, Joue and Mittelberg recommended to represent transitive actions through dynamic, pantomimic, habitual gestures, the study here suggests static and iconic gestures for the task of representing letters. It is an obvious conclusion from the results of these two studies, that gesture interaction is perceived natural or convenient, when it follows the principles of Embodied Interaction (Dourish, 2004) to portray the real world interaction. Looking at Grandhi, Joue and Mittelberg’s study, the gestures perceived as natural or appropriate were those that mirror exactly the same action from the real world and additionally from the user’s own perspective. Comparing to this study, it is not surprising that users preferred iconic and static gestures, since the task was not to describe the action of writing (for example relevant in a hand-writing application), but to find representations for letters. Hence, users were looking for gestural representations of the object they know from the real world, the Latin
letter, and simply found the solution in those that resembled the visual expression of the letter the most. In the context of this user test, this was pre-dominating the meaning-making mechanisms of the users, which is certainly related to the task, as mentioned. However, it could be implied that to a certain extent, the users were stuck to the obvious communication channel they consciously associate with writing, which is the visual expression of a word. This reminds of the poem by Loris Malaguzzi introduced in the beginning of this work. Have we been bereft our ability to perceive and answer to the world in the more subtle nuances of our communication skills? This question can not be answered by the results of this study, but they hint about the possibility of this being a factor in the meaning-making mechanisms and need to be further explored.

None of the users in the test remained in a position with the active hand alongside the body, but after a while started to lift the hands in front of the chest like with sign language for the deaf. Unfortunately, they could not provide a sufficient answer to the question why they think they changed their operating position. It seemed to happen just “automatically” (Jenny). Several reasons can be suspected for provoking the change of the operation position: 1) the ability to see the operating hand while looking on the screen, since all participants were novice users, 2) the perceived need for space around the hand in order to perform the signs properly, 3) the symmetric production of the punctuation signs with two hands (even though there was no need to actually have the two hands together in the front of the body), and 4) the innate urge to communicate with the computer as if it was a human conversation partner and thus, adopting the style of human-human sign language. If the latter is the case, then this would confirm the media equation (Reeves and Nass, 1998) and at the same time contradict Grandhi et al.’s (2013) findings, which in turn were contradicting the media equation for natural gesture interaction. The actual relationship between media equation and gesture-based interaction is left for other researchers to investigate.

Very interesting feedback about the supportive role of manual alphabets in writing tasks on part of the participants leads to the assumption that the simultaneous application of an alphabet like MATImyo that is very much resembling the Latin letters, might be a beneficial and complementing method for children or dyslexic people in the process of learning to write and spell. Our proprioceptive sense and muscle memory might contribute to establishing a more embodied link to the cognitive and often abstract process of writing and reading, which both can increase motivation and opens up for another, probably more suited processing channel.

Finally, studies concerning the socio-cultural acceptance of gesture-based interaction have focused on the actions of an individual in front of social norms (Williamson, Brewster and Vennelakanti, 2013; Rico and Brewster, 2010). This study has brought up another aspect of acceptance on a sub-cultural level. Participants associated with the “gamer culture” or very technically minded subjects agreed on that there is a common “cult” among gamers and “nerds” regarding their equipment and it is considered hard to bring in something new. This opens up for further research in order to get a more complete picture of reasons for not choosing gesture-based interaction.


7.5 Suggestions for future research

There is room for improvements considering the conduction of the study regarding the test setup and the scale of the study. It would be interesting to see the results of a similar test with optimized test conditions. Those are: a larger scale of the study with participants from around the world; either incorporating a truly “invisible wizard” or an actual working prototype for gesture recognition; extending the time of the testing from novice user to expert user; and an optimized and more efficient version of MATImyo according to the points mentioned in section 6.2, maybe even in combination with a word-based computer sign language, where MATImyo is just the manual alphabet for spelling tasks and accompanied by services like autocorrect and autocomplete. It would be even more beneficial for gaining insight into the actual user experience of gesture controlled writing, if the test scenario was comprising a multimodal interface in which the gesture-based interface is embedded complementing the other alternatives, as described in the scenario in section 1.1. The users’ preferred choice of using or not using the gestural alternative in such a competing interaction scenario would have to say a lot more about the user experience of gesture-based interaction (Satchell and Dourish, 2009; Selwyn, 2003) than a single-modal interface can reveal.

The power of the Latin alphabet obstructed all possibilities to search for more subtle associations, since the task was too strictly bound to the written representation. A suggestion is to test the association mechanisms again, this time without the written representations of the letters, but with their phonetic expression. This could lay the ground for a globalized gesture alphabet that is not related to a particular written alphabet.

Another suggestion for future research is to dig deeper into the rather philosophical questions about the relation of sign languages like MATImyo with Dourish’s Embodied Interaction. In this context, it would be a good idea to search for further possibilities to represent letters in an even more embodied way than simply forming the hand shapes in resemblance to the Latin alphabet, e.g. mouth shape and onomatopoeia.

Finally, it would be interesting to see an internationalized sign language for human-computer interaction emerge, and to investigate, if the computer actually has the power to spread this sign language around the globe, tearing down language barriers between all human beings of this planet.

8. Conclusion

In this study, a manual alphabet for gestural writing input with a myoelectric gesture control device was developed and evaluated in a user-centric approach. Both the design and evaluation processes were heavily coined by the theoretical framework of Embodied Interaction regarding the choice of methods, procedure and perspective on the results in order to arrive at a solution that is human-friendly and provides a natural, positive user experience. The quality of the alphabet was found to be well suited for the task with only a few letters that need more attention in order to meet the users’ ergonomic needs. It was remarkable how fast the participants were able to learn and apply the alphabet with an acceptable writing efficiency, given the fact that all were novices with MATImyo and the
interaction style itself. With this result, the first research question about the suitability of MATImyo as input language can be positively answered.

The user experience was in general positive and described as more engaging, but at times, users also felt frustration and strain on their hands. It is likely that those issues are changing over time, when the user develops from being a novice to an experienced user. Further, also technical issues with the test software had a negative effect on the user experience. Therefore, one of this work’s goals, namely to provide a “cleaner” assessment of the actual, authentic user experience of gesture-based interaction in writing tasks, is not fully achieved. However, the results show, that users are welcoming such an interaction style for their everyday computer work or specific tasks. The joy of being able to use the body instead of an uncomfortable input device when composing texts and being freed from the desk overruled the disadvantages for most of the test users. Hopefully, another and improved user test with an unbiased test situation can deliver insights into a more authentic user experience in the future.

Additionally, some other significant aspects emerged during the course of the study. Firstly, the choice of Embodied Interaction as theoretical framework proved to be very useful for meeting the needs of the users. It led most of all to the choice of very well-suited research and design methods with frequent involvement of potential users, which can be recommended for such a task. Secondly, the study revealed the association mechanisms of users when memorizing or recognizing hand signs as representation for a certain letter of the Latin alphabet: the visual resemblance is the predominating source for associations. Thirdly, socio-cultural reasons play a role in the choice of the interaction style. Finally, an interaction form like the here presented is beneficial for both deaf and dyslexic people, as emanated from the study.

With these results of the study, a novel and more natural method for writing on the computer was provided that is worth investigating further. The end-users could benefit from an improved version of MATImyo, according to the results from the user testing, and from the application of such an interface in general. The research community got a new piece of the puzzle about the bigger picture of the user experience of gesture-based interaction put in place. New research goals were proposed regarding design criteria of the input language, their compliance with Embodied Interaction, as well as aspects of meaning making and the way we interact with the computer. It is left to pose the ultimate question in this context: would it be possible to unite the world under one global computer sign language?
References


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Appendix 1: Material for the selection process

The material used for the selection process with users

Figure 3: The alternatives for the letters A–I composed for the selection process.

Figure 4: The alternatives for the letters J–R composed for the selection process.
Appendix 1: Material for the selection process

Figure 5: The alternatives for the letters S–Z composed for the selection process.
Appendix 2: Resulting alphabets

Resulting alphabets

Figure 6: These are the alphabets consisting of the hand shapes that received the highest scores in the categories Latin alphabet (upper left), Ergonomics (upper right), and Embodied Interaction (below), which is a new category that is formed by the categories that are related to associations. To the left, the Latin alphabet is included in this category, to the right, it is excluded, since it is unsure to which extent the resemblance to an artificial construct is to be considered embodied.
Figure 7: The alphabets with the highest overall scores (upper left) and the users’ favorites (upper right), as well as possible solutions under the aspects of having distinctive signs (lower left) and an optimal alphabet according to user ratings for a vision-based system (lower right).
Figure 8: The final result showing the chosen hand signs for MATImyo. A, B, F and H are new signs elicited from the user testing or added by the designer. Y, P and U are originally used for other letters in the corresponding national sign language, but were found to fit better for the current configuration.
Figure 9: The tutorial for learning MATImyo showing two perspectives of the letters A-H with additional explanations.
Appendix 3: Tutorial for learning MATImyo

Figure 10: The tutorial for learning MATImyo showing two perspectives of the letters I-Q with additional explanations.
Figure 11: The tutorial for learning MATImyo showing two perspectives of the letters R-Z with additional explanations.
Figure 12: The tutorial for learning MATImyo showing the signs for punctuation and text editing with additional explanations.
Appendix 4: Texts for user testing and practicing

Texts for user testing and practicing

in a cabin in the woods
little man by the window stood,
saw a rabbit hopping by
knocking at his door.
help me, help me, help me, he said,
before the hunter shoots me dead.
come, little rabbit, come inside,
safely you may hide.

itsy bitsy spider climbed up the waterspout.
down came the rain
and washed the spider out.
out came the sun
and dried up all the rain.
itsy bitsy spider climbed up the spout again.

mary had a little lamb,
his fleece was white as snow,
and everywhere that mary went,
the lamb was sure to go.
Interview guide

Introduction
In this study, I am trying to investigate the potential of the manual alphabet MATImyo that was developed for the usage with a myoelectric gesture control device. I am interested in how suitable the alphabet is when writing texts and how it feels. Keep in mind, that this user test is not about your performance, no one will judge you for your writing skills with MATImyo. It’s about the experience and nothing you say can be wrong as long as it is the truth. You have the choice to decline answers or even stop the testing or interview whenever needed.
The results from the study will be published for scientific purposes, but you will be anonymous in the study and no one is allowed to look at the video or listen to the recording without your permission. Is it ok to record the user testing both with video and sound?

Before the experiment:
Demographics:
- Gender
- Age
- Area of profession/studies/special interests
- Cultural background
- What is your primary alphabet?
  - Did you learn or use other alphabets as well?
- Are you
  - concerned about what others think of you?
  - concerned about living by social rules and norms?
  - open for new possibilities?
  - interested in technology?
    - Like a nerd or rather like a technophob?
  - interested in languages?
    - For communication?
    - Linguistics and structural comparisons?
- Do you have experiences in
  - Gesture interaction?
    - Which (technologies, interaction styles)?
    - What was your experience (positive/negative)?
  - Sign language?
    - Which (what kind of sign language)?
    - How was your experience (easy/difficult)?
- Do you think it is hard to learn sign language for computer interaction?
  - For you?
  - For the majority?
  - If you learn it from birth?
  - Or from the 1st class in school parallel with the Latin alphabet?
  - Do you think it would be easier for children to learn the sign language alphabet or the written (Latin) one?
- Do you see it meaningful to learn sign language?
  - In general? Why?
  - For computer interaction? Why?
- How do you think gesture-based interaction looks like?
  - In general?
  - In the context of everyday tasks?
Appendix 5: Interview guide

- Is gesture interaction appropriate at the workplace? At any workplace?
  - What is needed to make it appropriate?
    - Size of the gestures?
    - Support from the boss?
    - Own office?
- How do you think you would be perceived by others when you interact through gestures?
  - Do you think that you would look stupid and feel ashamed, if someone would see you interacting with the computer through gestures?
    - In which contexts?
    - What kind of persons do you think would feel like that (character traits)?
- You are about to test a sign language with the MYO armband for computer interaction. How do you think this kind of interaction will feel?
  - Cognitively?
  - Physiologically?
  - Emotionally?
- How do you like the standard interface of (physical) keyboard and mouse?
  - Any problems with that?
  - How do you feel when interacting with it?
    - Now
    - When you were learning the standard interface?
- Have you ever actively looked for alternative interaction styles?
  - What were you looking for?
  - What did you find?

After the experiment:

User Experience
- What was your user experience during the test (if you can, try to eliminate bias from the test situation itself)? How did it feel?
  - Cognitively
  - Physiologically
  - Emotionally
  - Was it different from what you expected it to be? How?
- Would you want to continue with such an interaction style, given that technical issues are eliminated and a proper sign language would be provided? Why, why not??

MATImyo's quality
- The sign language itself, how did that feel and work?
  - Any suggestions?
  - Which letters were hard to perform?
  - Which letters were hard to remember?
  - Because of which criteria did you memorize the sign?
    - Latin alphabet
    - Mouth shape
    - Other associations
    - Onomatopoetic aspects
  - Do you think it fits within Embodied Interaction, that means that it fulfills both the criteria of being through the body and having a connection with the actual meaning of the action?
- How long did it take for you to memorize the hand signs for this sign language?
- How far do you think you have come now in % (100% would be someone who is a native signer)?
- How far do you think you have come with the standard interface, if 100% is error-free writing in record time?
Appendix 5: Interview guide

- Any aspects about the learning curve of this sign language alphabet in comparison to learning writing on the keyboard?
  - Which felt easier to learn? Cognitively?
  - Which was quicker to learn? To get to the point you are at with the sign language right now?
  - Which do you think will lead to a more successful learning curve after some time of practice? Will you ever be able to write with a sign language as good/fast as with the keyboard? Or even better?
  - Which do you think will actually be more efficient?
  - Which do you think will make you feel better?

- Given a scenario, where such a manual alphabet is part of a much more efficient and comprising sign language, where you express normal words with a single sign and only use the alphabet in some cases (no T9 working, foreign language, programming). You are supported by auto-correction and auto-completion. The gestural interface is, in addition, only a part of a multimodal interface, where you have access to voice and standard-like interfaces as well. You are at home and do whatever you want to do while writing an e-mail or similar. No technological issues. Do you think that based on your recent experience with this manual alphabet, this kind of interaction makes sense? Would you like that? Why? Why not?

  Especially questions to deafs or those who are experienced in sign language:
  - How did it feel to interact with the computer in this way instead of with a human?
  - Is it confusing in any way that the computer does not respond to other parts of the human body language as a human conversation partner would do? Or would it be necessary?

- Anything else about this test, the sign language, the interaction style or what else I need to know?