Influencing Factors on Multimodal Interaction at Selection Tasks

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ABSTRACT

When developing multimodal interactive systems it is not clear which importance should be given to which modality. In order to study influencing factors on multimodal interaction, we conducted a Wizard of Oz study on a basic recurrent task: 53 subjects performed diverse selections of objects on a screen. The way and modality of interaction was not specified nor predefined by the system, and the users were free in how and what to select. Natural input modalities like speech, gestures, touch, and arbitrary multimodal combinations of these were recorded as dependent variables. As independent variables, subjects' gender, personality traits, and affinity towards technical devices were surveyed, as well as the system's varying presentation styles of the selection. Our statistical analyses reveal gender as a momentous influencing factor and point out the role of individuality for the way of interaction, while the influence of the system output seems to be quite limited. This knowledge about the prevalent task of selection will be useful for designing effective and efficient multimodal interactive systems across a wide range of applications and domains.

Keywords

natural human computer interaction, multimodal interaction, user study, gender differences, selection task, input, output

1. INTRODUCTION

Advances in processing power, sensory technology, and recognition techniques in recent years gave rise to new forms of interaction. Respectively a multitude of input modalities is available for both, users and developers of HCI systems. Nowadays, even handheld systems are able to perform real time speech recognition and static computing environments can be equipped with gesture sensors that are able to recognize 3D movements of individual body parts. Thus more and more effort is dedicated to systems allowing users to interact the way they find natural, freeing them (at least partially) from the necessity to learn the interaction language the system understands. Today the burden lies on the system's side to understand the user's language. This is not an easy task and researchers have difficulties finding out why people interact with computing systems the way they do. Although there is empirical evidence for some kind of "rules" in different contexts, special domains, and special tasks at hand, little is known about general factors that influence people's way of interaction with multimodal systems. One basic question that comes to mind: Which modality do users choose naturally, if they are not constrained by device limits or by an a priori defined interaction language, i.e. strictly limited interaction possibilities in each interaction step? The presented study should help to answer this question.

The paper is structured as follows. Related work on this topic is presented in the next section, which leads to the specific research questions about influencing factors (e.g. the role of gender) that we are going to answer with our user study. The experimental design section states the specific problem instance chosen for the study and the entire data acquisition process, and concludes with known limitations of the design. The results section then lists all findings relevant to the research questions. Within the discussion, the findings are critically examined before our conclusions are summed up and a course is set for future research.

2. RELATED WORK

There have been several studies investigating the use of multimodality in different contexts. Some of them have relevance to our own study by already revealing different influencing factors on the use of or preference for certain modalities.

First of all, the application domain, and hence the involved tasks, can have a momentous influence. Several researchers report this fact on different levels of detail. Ren et al. [16] found out, that for a CAD application, users prefer pen+speech+mouse mode, while in an independent study with other users, pen+speech mode is preferred for a map application. More detailed influence of the task at hand is reported in [11], were results show that users prefer touch input for denoting positions while speech is preferred for abstract actions. Similarly, Ratzka [14] reported mainly touch input for selecting options on screen and speech use for text input.

Abstracting from the task itself, several researchers found the complexity of the task to be of importance for the use of multimodality. Oviatt et al. report in [13] that the likelihood of multimodality increases with the cognitive load of the task. Similarly Jöst et al. show that the more complex the task is, the higher are the usability ratings for multimodal interaction compared to unimodal interaction [6].

The presentation of a task is another influencing factor on the choice of input modalities users make, when performing it. De Angeli et al. proved this with a form-filling task

[3]. Presence of short labels encourages users to make redundant references, i.e. co-occurrence of mouse pointing at an entry field and a fully determined verbal specification. They also found out that feedback on mouse pointing gestures (i.e. visually detectable change of the pointed object in terms of highlighting) increases the likelihood of multimodal inputs. Despite the presentation in a single modality, the very use of an output modality by the system changes the modalities users choose for input. In a smart home environment, Bellik et al. [1] show that verbal output modalities like text and speech lead to speech input, while graphics output (icons) leads to touch screen use. The authors assume some kind of "influence power" for each output modality that gets subsumed when multiple modalities are combined. Using all available modalities (in that case text, graphical icons, and speech) for system output, users still prefer speech over touch and remote control input.

Another important influencing factor is the situational context in terms of privacy of the situation where the interaction takes place. In addition to the influence of task complexity, the study in [6] proofs a declining willingness to use multimodal interaction with decreasing intimacy of the relationship between the user and other persons around. Going a little more into detail, Wasinger and Krüger report that users prefer to use non-observable modalities like handwriting and touch gestures in public environments where they are in presence of strangers [16]. Likewise, Reis et al. report in [15], that speech is not used in public environments and additionally emphasize the influence of the privacy of information that is exchanged with the system.

The user itself also plays a decisive role for the interaction. De Angeli et al. identified computer literacy (expert vs. naive users) as deeply influencing the likelihood of multimodal occurrence in their form-filling task [3]. Expert users clearly preferred to interact multimodally, whereas naive users showed no preference between unimodal and multimodal inputs. This could be due to the fact, that expert users are more curious about technology and innovation, as Reis et al. report the tendency of their users (that were all familiar with computer and mobile phone use) to use new and uncommon ways of interaction [15].

Surprisingly, from the aforementioned studies, only Wasinger and Krüger [17] have examined the role of gender for the interaction. Their usability test reveals gender differences in modality preferences. In their real world study in a public environment, women report lower ratings on feelings of "comfortable using speech" than men and higher ratings of "hesitant" and "embarrassed" then men when using speech. Similar differences hold for the use of pointing gestures on real world objects.

Summing up, there has been much work on different factors that influence multimodal interaction, mostly derived from usability studies or Wizard of Oz experiments of complete systems with a complex mixture of tasks. All these studies provide interesting insights into the complex dependencies between the user, the system, and the interaction in-between. However, their transferability to new systems from different domains remains difficult. Be it that new forms of interaction replaced the employed modalities of these studies today (like pen input through direct touch) or just that the tasks are too special for a reliable transfer of the findings to different domains. Above all, our understanding of the role of the user itself as the ultimate instance deciding the way of interaction seems still very limited.

3. RESEARCH QUESTIONS

The goal of the study presented in this paper is to provide the basis for a general applicability of influencing factors on multimodal interaction. Such influencing factors could not only be used in the fusion of input modalities, but in the fission of output modalities as well. For this reason, we investigate selection as a common and prevalent task in almost every system. With respect to state of the art technologies and the increasing success of natural ways of interaction offered by touch screens, gesture, and voice recognizers, we decided to include only those ways of interaction, that get along without auxiliary devices the user has to operate. This means we investigate those input modalities that are natural in human communication in the form of speech, gestures and touch. As well-known output modalities of the system, visual display and speech output are employed.

The overall research questions we are trying to answer are as follows:

- How does the use of input modalities for selections depend on the user's gender?
- How does the use of input modalities for selections depend on the user's personality traits?
- How does the use of input modalities for selections depend on the user's affinity towards technical systems?
- How does the use of input modalities for selections depend on the way the task and the selectable items are presented by the system?

The specific operationalizations of these questions are given in the according result sections of this paper.

4. EXPERIMENTAL DESIGN

The study was performed on a stationary wall-mounted system, as these kinds of systems will presumably be among the first to be equipped with sensory technologies enabling the intended natural interaction. As an application scenario, one could think of public information displays for floor plans, where guests can read up on the different facilities of a building, or interactive advertising in shop-windows. At home, there could be an interactive TV set or a home automation system. Basically, all scenarios involving an interactive wall mounted display have selection as a fundamental task to be performed.

In order to minimize the effort and to avoid the risk of error-prone sensory systems, a Wizard of Oz scenario was implemented, where an operator in a separate control room interpreted all user inputs utilizing audio and video transmission from the interaction scene (see Figure 1). Using a remote desktop connection to the test system, an interactive Microsoft PowerPoint presentation was controlled by the operator as response to observed user actions. Figure 2 shows a user in front of the system as he performs a selection via a pointing gesture. When asked after the study, none of the subjects reported suspicion of a human operator behind the system behavior, proving the technical feasibility of the experimental design.

Figure 1: An operator in the control room observing the user interaction to trigger the system's reaction

Figure 2: A user in front of the test system performing a selection using a pointing gesture

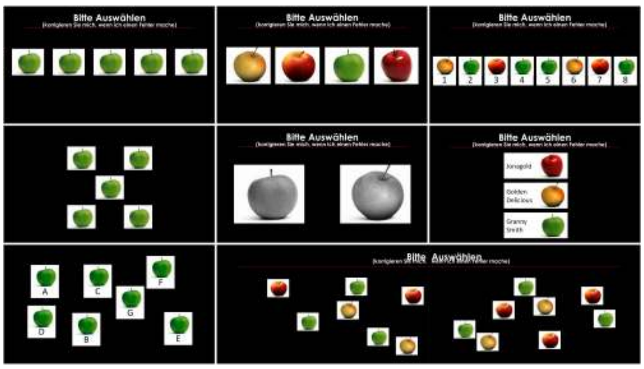

Figure 3: Eight out of the 23 selection tasks, differing in the amount of items, arrangement and presentation styles

4.1 Tasks

The selection tasks to be performed consisted of graphical icons of apples as a simple and neutral abstraction of selectable items. To allow for long distance interaction, the tasks were spread over two screens and the participants were free to move in space. There were 23 selection tasks in total, with varied amounts of items, arrangements, and presentation styles as listed in Table 1. Figure 3 shows some examples of actual selection tasks, the complete list of all 23 can be found in Appendix A. Note that the task description, whether textual, spoken, or mixed, only stated to select an apple (e.g. "Select one, please!"), not which one. This way, the participants were totally free in which apple to select (but exactly one) and how to perform the selection.

In order to avoid the monotony of 23 selections in a row and to simultaneously record data for research colleagues, there were 27 other tasks not in focus of this paper. These consisted of different riddles and puzzles like for example mathematical word problems, picture puzzles or "find the hidden number" pictures. Additionally, these other tasks should help to distract subjects from the selection tasks, so that they don't reflect too much on the way they perform them. All tasks were presented in randomized order to avoid sequence effects.

4.2 Participants

The participants were acquired through notices posted on campus and were paid for their attendance. Overall, 53 volunteers took part in the study, with an average age of 21.9 and a standard deviation of 2.4 years. There were 27 female and 26 male participants, mostly students with no background of computer science (47.2% medicine, 13.2% mathematics, 9.4% biology/chemistry, 7.5% physics, 7.5% mathematical biometrics and 15,2% others). All of them were native speakers.

4.3 Experimental Procedure

After being greeted by a staff member, the participants were informed about our research consortium and its general goals. It was stated, that a novel system is to be tested, that should be capable of understanding almost everything the user is doing, due to its large amount of sensors (cameras, laser-scanners, directional microphones etc.). Then they were asked to sign a letter of agreement, and completed standardized questionnaires on personality traits [4], and their technology affinity towards electronic devices [7]. After that, they were equipped with a radio headset microphone, briefly introduced to the system, and then left alone to perform the test.

The test itself began with a greeting by the system and a faked calibration sequence, which introduced the different kinds of possible interactions (speech, touch and pointing gestures). Then, the overall 50 tasks (including the 23 selection tasks) were presented in randomized order. Regarding the selections, the operator had clear instructions on how to react upon user actions. Selections were triggered by a direct touch of the user on the object, by discriminating it verbally (e.g. "the red one", "the upper one", etc.), or by performing a pointing gesture on an apple (clearly remaining on one object or triggering the selection by an additional utterance like "this one"). When an apple was selected, it was highlighted on screen and a confirmative sound was played, before proceeding to the next task.

Table 1: Variables describing the variation points used to build up the 23 selection tasks

Variables	*Task description* for the user	*Labeling* of objects	*Diverseness* of objects	*Number* of objects	*Arrangement* of objects	*Color mode* of objects
Values	• purely textual (graphic output) • purely linguistic (speech output) • mixed	• none • numerical • alphabetical • textual	• identical • partially identical • different	• 2 • 3 • 4 • ≥ 5	• horizontal • vertical • diagonal • like dice pips • random	• black-and-white • colored

When the test was over, the staff member re-entered the room and instructed the participants to fill-out additional questionnaires and to give their demographical data. Finally they were informed about the Wizard of Oz procedure and asked to maintain confidentiality until the end of the entire study.

4.4 Data Recording

For the purpose of this study the following data was recorded:

- Log files: The actions triggered by the wizard were written into a log file containing the resulting task order and all system events (as reaction to the observed subject behavior) in chronological order.
- Video recordings: All sessions were observed by two cameras, one in front of the object, and another from an overhead perspective behind the test subject.
- Audio recordings: Two audio streams were recorded, one from the lightweight radio headset microphone, and another from two directional microphones covering the area in front of the system.
- Questionnaires: For the personality traits, participants completed the German version [4] of the NEO-Five Factor Inventory (NEO-FFI) by Costa & McCrae [2], resulting in scores between 0 and 48 for Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. For measuring their affinity towards technical devices, they filled out a TA-EG (Technology Affinity – Electronic Devices) questionnaire [7], resulting in scores between 1.0 and 5.0 for Enthusiasm, Competence, as well as Negative and Positive Attitude.

4.5 Labeling of Data and Independent Variables

Each subject's recordings were labeled using the video annotation tool ANVIL [8]. As dependent variable, the modality of every interaction leading to a selection was labeled with one of the following:

- *Speech*, e.g. just saying: "The rightmost one"
- *Gesture*, e.g. just pointing at an object
- *Touch*, e.g. just touching the object of choice
- Any multimodal combination of the above, e.g. *Speech+Gesture* when using deictic references like "this one" together with a pointing gesture.

Participants' demographics, questionnaire results (NEO-FFI and TA-EG), and all task specific data (c.f. Table 1) were used as independent variables for the statistical analysis.

4.6 Statistical Analysis

All statistical analysis was conducted with IBM SPSS Statistics. Since normal distribution was not always given in the data, and to avoid a mix-up of different statistical methods, solely non-parametric tests were applied. Regarding our research questions, three different tests were chosen. Dependencies between the used input modalities and the way selections are presented were calculated using the Wilcoxon matched-pairs signed-rank test. For correlations between the input modalities and personality traits or technology affinity, Spearman's rank correlation coefficient was used. Significance of gender differences was analyzed with Mann-Whitney U tests. The applied level of significance was 5% across all tests.

4.7 Limitations

The chosen experimental design described above has some limitations we are ware of, as described in the following paragraphs.

Study Design Issues.

Regarding the selection tasks in retrospect, their assortment was not optimal. Initially, the dependencies on the presentation style should be examined in more detail, e.g. what is the influence of the number of selection objects and their arrangement. Due to the limited number of selection tasks, however, it sometimes lacked necessary pairs that only differ in the aspect of interest. So only few aspects of presentation style (task description, labeling, and distinguishability) could be examined.

Instead of recording dependent samples by having all subjects performing all selection tasks, analysis would have been easier if subjects were divided into separate groups. This would have enormously increased the necessary number of subjects, though.

Embedding the selection tasks into the others indeed prevented repetitive tasks and distracted subjects from the way of selection. On the other hand, some influence on the way of interaction cannot be excluded, although we tried to minimize this influence by an even ratio of tasks to be performed by speech and touch.

Issues of the Participant Demographics.

With an average age of 21.9 years and a standard devia-

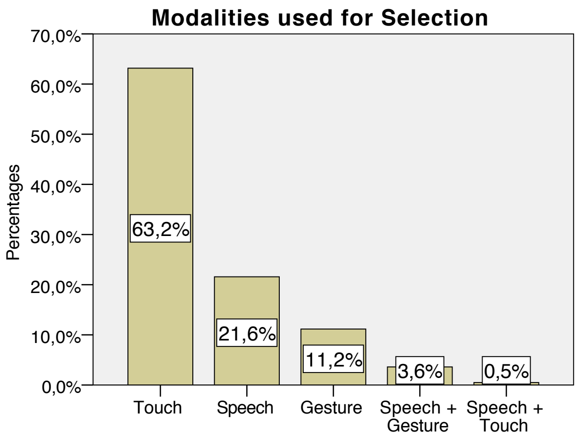

Figure 4: Overall percentages of the used modalities for all 1219 selections performed during the study

tion of 2.4 years, the participants are quite young. Also the educational background is very homogenous with nearly half of them being medical students. These demographics yield accurate results with little danger of producing overgeneralizations. Nevertheless, statistical inference on the parent population of users seems difficult, because interaction with technical systems certainly depends on habit and daily experience of the observed population. Additionally, the validity period of such a user study's results is always limited, as technology progresses and market penetration of standards changes. It is reasonable, for instance, that nearly all participants of the study at hand have experience with touch screen devices like smartphones, whereas familiarity with natural voice interaction can still be regarded as quite limited.

5. RESULTS

With 53 participants, data from 1219 selections were available for analysis, although for testing of specific conditions (regarding presentation style) only a subset of matched pairs was used.

The core issue of our analysis deals with the percentaged use of input modalities for the selection of objects under different conditions. Overall, the subjects show a clear preference for touch input, followed by speech and pointing gesture inputs. Multimodal inputs are used very rarely. Figure 4 shows the percentages of all modalities used during the study.

The following sections describe our findings corresponding to the four research questions stated in Section 3 and the observed overall shift in modality use.

5.1 The Role of Gender

Before studying the influence of gender on the use of input modalities, we first describe gender specific differences in the NEO-FFI and TA-EG values.

Differences in Personality Traits and Technology Affinity.

Figure 5 and Figure 6 show the results of the NEO-FFI and TA-EG questionnaires for male and female participants. Throughout all personality traits of the NEO-FFI, females score higher values then males (similar to the German Norm [9]), although only the difference in Agreeableness is significant (N =26m/27f, Mann Whitney: $U = 206$, $p = .01$). Within the technology affinity scores of the TA-EG, the situation is contrary with males scoring higher than females throughout all values. The male scores for Excitement and Competence are notably higher with significant differences (N = 26m/27f, Mann Whitney: $U = 70$, $p < .001$ and $U = 223$, $p = .02$).

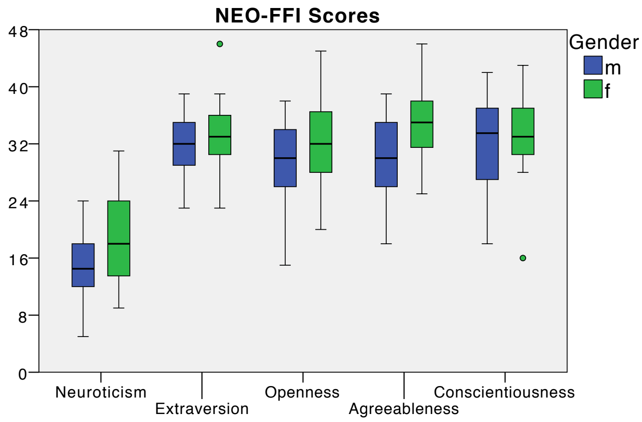

Figure 5: NEO-FFI values for males and females

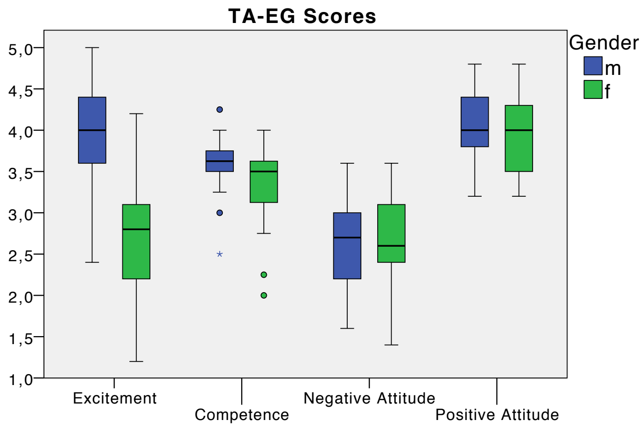

Figure 6: TA-EG values for males and females

Differences in Modality Use.

Percentaged usages of modalities differ greatly between male and female participants. Figure 7 illustrates these differences. While females highly favor touch interaction to select objects (82.7% touch, 10.1% speech, 4.7% gesture), males tend to use other modalities way more often (42.8% touch, 33.4% speech, 17.9% gesture). Multimodal ways of input for selection tasks are quite rare for both genders. The mean numbers of touch, speech, and gesture modalities differ highly significant (N = 26m/27f, Mann Whitney: $U = 152.5$, $p < .001$; $U = 184$, $p = .002$; $U = 225.5$, $p = .01$).

5.2 Influence of Personality Traits

Can personality traits serve as a predictor for modality usage? We tried to answer this question by performing correlation analyses on the results of the NEO-FFI question-

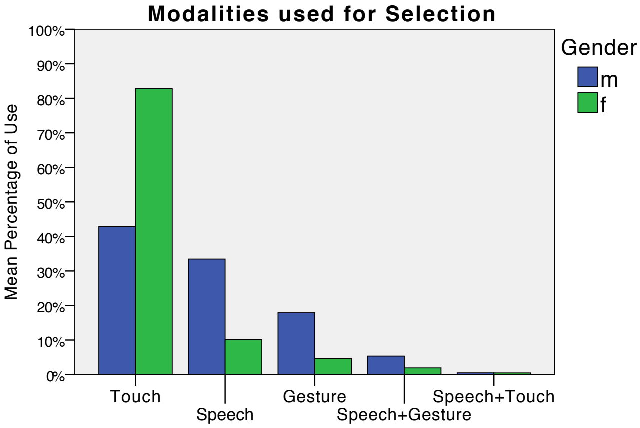

Figure 7: Mean percentages of modality use for male and female subjects performing a selection

naire. We decided to perform separate analyses for each gender due to the differences in the mean NEO-FFI scores and in modality use. Prior to the correlation calculation, outliers within the NEO-FFI scores were removed from the data (two female subjects, cf. Figure 5). Regarding the modalities, only those were taken into account that had high enough frequencies of usage, so that they exhibited a real distribution and did not merely consist of outliers. So for male subjects, touch, speech, and gesture modalities were taken into account, while for females only touch remained in consideration.

For the all-female group of participants, there is no significant correlation between any of the personality traits and the number of selections per touch.

For the male subjects, there are positive correlations between Extraversion and Openness and the number of speech uses, which are statistically significant by Spearman's rank correlation (N = 26, rs(24) = .429, p = .029 for Extraversion; rs(24) = .391, p = .048 for Openness). Figure 8 and Figure 9 illustrate these ties.

5.3 Influence of Technology Affinity

Similar to the personality traits, we performed gender-specific correlation analyses on the results of the TA-EG questionnaire. Outliers within the TA-EG scores were removed (three male and two female subjects, cf. Figure 6). For the same reasons as above, the modalities taken into account were: touch, speech, and gesture for males, but only touch for females.

This time, no significant correlations exist for male subjects. However, female subjects show a significant positive correlation between Competence and the number of selections via touch (N = 25, rs(23) = .421, p = .036). At the same time, there is a significant negative correlation for Negative Attitude and the use of touch (N = 27, rs(25) = -.461, p = .016). Figure 10 and Figure 11 illustrate these ties.

5.4 Influence of Presentation

Regarding the influence of the way the task and the selectable items are presented on the use of input modalities, three aspects of presentation are studied: The modality of the task description, the labeling of selection objects, and the distinguishability of the objects.

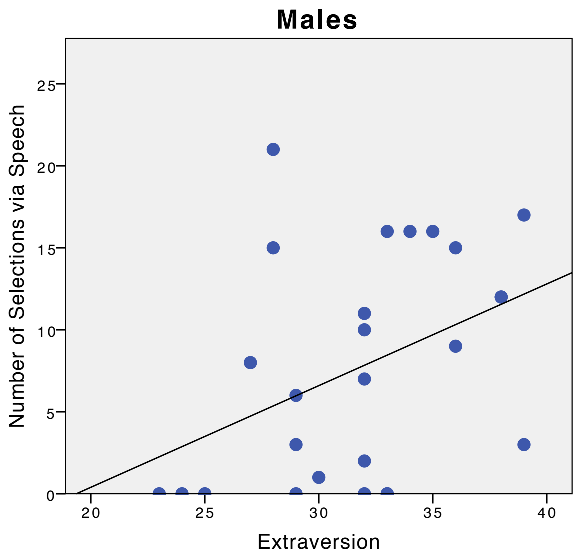

Figure 8: Extraversion as a predictor for the use of speech for male subjects. The regression line shows the positive relationship.

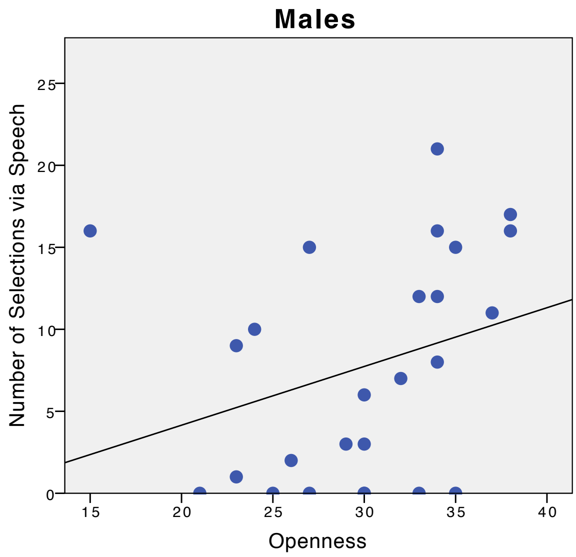

Figure 9: Openness as a predictor for the use of speech for male subjects. The regression line shows the positive relationship.

Task Description.

The task description was realized as text on the screen, e.g. "Select one, please!", as a verbal system output "Which apple do you want?", or in a mixed way. Four tasks (two matched pairs) where selected for the analysis: two of which had a purely spoken task description, the other two had a textual description.

As illustrated in Figure 12, the touch interaction predominates the other modalities under both conditions. Nevertheless, the mean percentage of selections per user via touch decreases from 61.3% for the textual description to 52.8% for the spoken one. At the same time, speech interaction

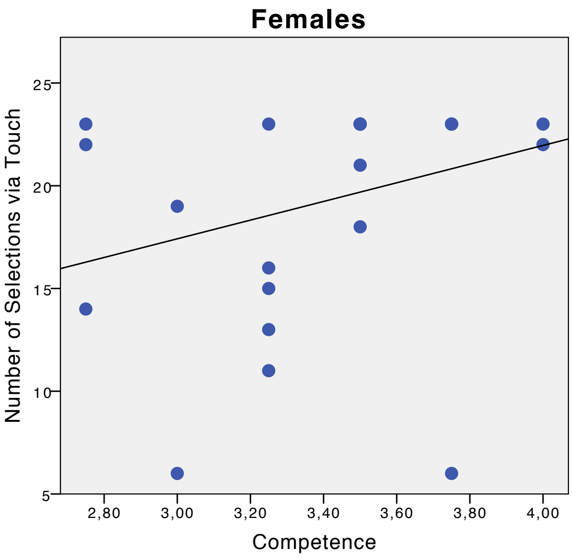

Figure 10: Competence as a predictor for the use of touch input for female subjects. The regression line shows the positive relationship.

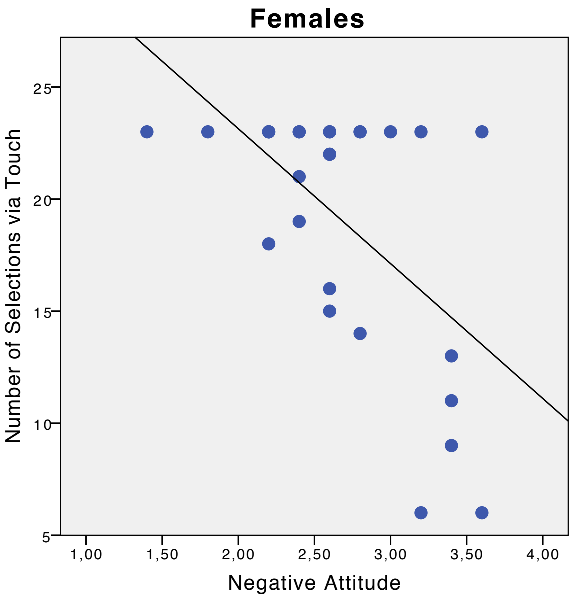

Figure 11: Negative Attitude as a predictor for the use of touch input for female subjects. The regression line shows the negative relationship.

percentages increase from 22.6% to 34.9%. The Wilcoxon test reveals, that these differences are significant (N =53, speech: Z = -2.71, p = .007; touch: Z = -2.18, p = .029). The other modalities, gesture and multimodal ones, show no significant changes. A per gender analysis shows no significances, due to the sample sizes becoming too small when only analyzing four tasks.

Labeling of Selection Objects.

Investigating, if the presence or absence of textual labels on the selection objects has an influence on the use of input

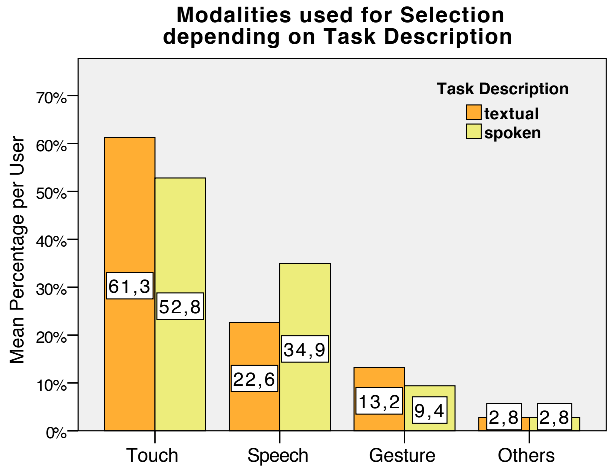

Figure 12: Mean percentages of used selection modalities per user in textual and spoken task description conditions

modalities, four tasks (two matched pairs that offered the same apples) were selected for analysis. Two tasks contained visible labels (one with single letters and one with the apples' sorts written next to each object) while the other two showed no labels.

The average percentages of used selection modalities for both conditions do not significantly differ from each other. In both cases, touch interaction clearly predominates the other modalities in usage percentages with 63.2% in labeled and 65.1% in unlabeled conditions, respectively. With 22.6% and 19.8% usage, the values for the speech modality differ only slightly, likewise for the gesture modality with 11.3% and 10.4%. Again, the usage of the other modalities and multimodal combinations is only marginal. Again, per gender analysis gives no further insights.

Distinguishability of Selection Objects.

To test, if the distinguishability of selection objects has any influence on the user's applied modality, we chose four tasks with discriminable objects, and four tasks with objects hard to differentiate. While the former contained labels and different apples, the latter consisted of unlabeled identical apples or different apples presented in black-and-white.

As with the labeling, subjects show no significant change in modality use. However, the use of speech increases from 20.8% (not discriminable) to 24.1% (discriminable). The overall usage distributions are as follows: 63.2% touch, 20.8% speech, 12.7% gesture, and 3.3% others for the tasks with not discriminable objects. For the tasks with discriminable objects the results are: 61.8% touch, 24.1% speech, 11.3% gesture, and 2.8% others. Per gender analysis does not reveal any significance, either.

5.5 Other Observations

The following sections describe other interesting observations made during the data analysis. It should be noted, that these observations solely represent descriptive statistics and did not undergo statistical analysis as this would require are more elaborate experimental design focussing on the respective factors.

Modality Shifts over Time.

Although not in focus of our research questions, we decided to look at the usage of modalities over time, too. To do this, the 23 tasks were split into (nearly) quarters: the first five tasks any user performed were taken into quarter one, while the remaining 18 tasks were split into groups of six for the second, third and fourth quarter. Note, that the task order was randomized for each participant, so the tasks in the four quarters were most likely different for each participant. As illustrated in Figure 13, both genders tend to increase their speech user over time. While for females speech remains at quite a low level (with only about 16% maximum) compared to touch use, males increased their usage of speech up to 42%, even exceeding touch use in the 4th quarter of the tasks.

How Speech was Used.

One natural question that comes to mind when speech is involved is: How was it actually used? So we decided to investigate all occurred verbal selections in more detail. The following ways of selection can be differentiated when using speech:

- *relative spatial*: the selected object is described by its relative location to the other objects. E.g. "the second one", "the topmost".
- *semantical*: the selected object is described by its visual or other properties that differentiate it from the others. E.g. "the red one", "object A".
- *relative spatial* - semantical mixed: the selected object is described in a mixed way by combining its relative location with its visual properties. E.g. "the green one on the left".

The possibilities to use one of the above ways of verbal selection largely depend on the way the selectable objects are presented. Thus, we separated selection tasks with and without labeling and related them with the complexity of arrangement and the diverseness of objects. The complexity of arrangement depends on the number and arrangement of objects (cf. Table 1), while the diverseness just states, if identical, partially identical, or different objects are presented. As illustrated in Figure 14, it can easily be seen that with labels, users prefer semantical selection. Vice versa, if there are no labels, they prefer relative spatial selection. When objects are labelled, semantical selection also clearly dominates the other ways of selection. When there are no labels, it gets more diverse. As the complexity of arrangement increases (the upper right chart in Figure 14), users start to use the mixed way of selection. This seems obvious, as when there are more objects on the screen, they usually are harder to discriminate. On the other side, when the objects are more diverse (the lower right chart in Figure 14), users prefer to use the semantical selection over the relative spatial selection.

6. DISCUSSION

The results on the overall use of modalities show quite a strong predominance of touch input and nearly no use of multimodal inputs during selection tasks. This fact strengthens some of Oviatt's Ten Myths of Multimodal Interaction, e.g. "Myth #1: If you build a multimodal system, users will interact multimodally." and "Myth #4: Speech is the primary input mode in any multimodal system that includes it." [12]. This could have multiple reasons. First of all, the selections in our study are very simple. With the findings in [6] and [13], that multimodality is promoted by the complexity and cognitive load of the task, this would explain the low number of multimodal inputs. Another factor leading to such high usage rates of touch input may be the participant's demographics. All participants were quite young and are used to touch screen technology, as some of the subjects reported after the study. Lastly, the (perceived) level of privacy during the study could be an influencing factor that perhaps prevented some users of using speech or pointing gestures (cf. [17]). Although subjects were on their own during the interaction, we cannot foreclose that the knowledge about the recordings and the clearly visible technical equipment lead to some feeling of surveillance similar to situations were strangers are in presence.

Regarding the role of gender, a remarkable influence is certifiable. Wasinger and Krüger's findings from retrospective interviews [17] that women feel less comfortable using speech are confirmed with the real interactions in our study. While 63% of the female subjects never used speech, so did only 27% of the males. Additionally, women's reliance on touch was much greater than that of males. While 83% of all female selections where done by touch, males performed more selections by speech and gesture (51% altogether) than by touch (43%). This shows, that males tend to use different input possibilities much more often than females do. This imposes special considerations when designing adaptive and user centered interactive systems.

Personality traits can be a predictor of modality use, as the significant correlations for male subjects demonstrate. Both Extraversion and Openness promote the use of speech to select objects. The reason for this could be an increased willingness to test a system and available input modalities, similar to findings of Reis et al. [15]. Such an obvious tie could not be found for female subjects, as their speech usage was too rare.

Instead of that, only women show an interesting correlation between the Competence and Negative Attitude scores of the TA-EG questionnaire. While Competence slightly increases the use of touch input, Negative Attitude clearly reduces it. The positive correlation of Competence and touch input could be a consequence of practice. It is comprehensible that women familiar with using state of the art technology like touch enabled smart phones, judge themselves as being more competent with electronic devices. The negative correlation for Negative Attitude could stem from a reduced willingness of women to directly interact with something they do not like by physically touching it.

Regarding the presentation, we could show that speech output (verbal task description) enforces the use of speech by the user, too. This corresponds to Bellik et al.'s findings[1]. In contrast to the results of De Angeli et al. [3], we could not report a significant influence of the presence of labels for the interaction, although the tasks of both studies are not directly comparable. Generally speaking, the presentation did play a surprisingly small role for the choice of input modalities during selection tasks. Especially the distinguishability of objects did not promote the use of speech in a significant way, even though discriminable objects make the verbal description very easy.

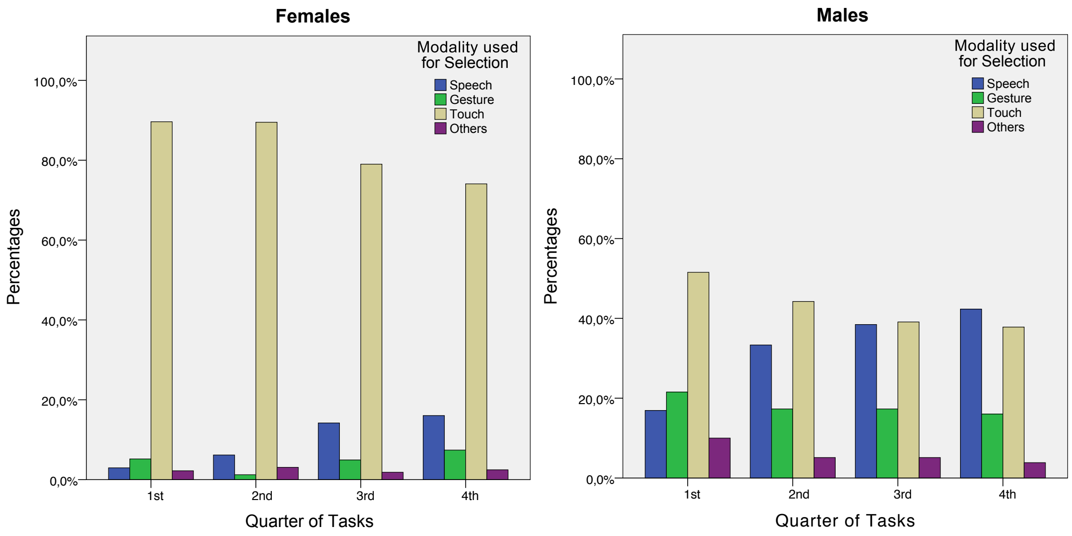

Figure 13: Mean percentages of used selection modalities for both genders in the four quarters of the selection tasks

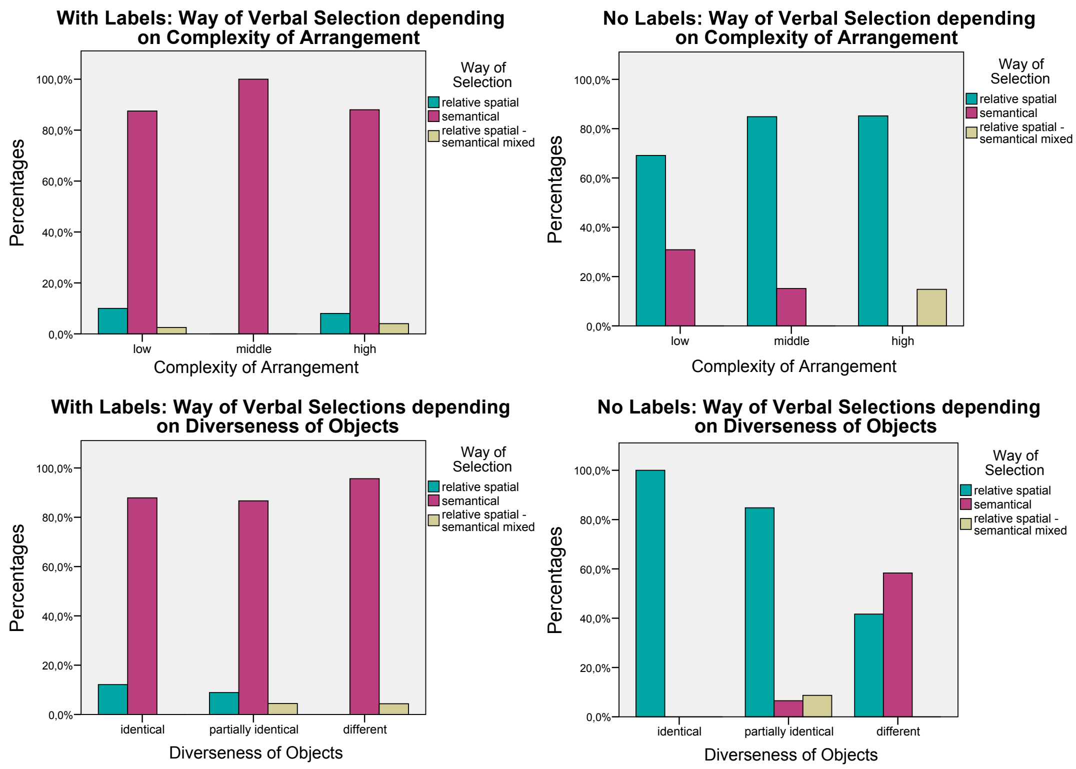

Figure 14: Way of verbal selections with and without labels depending on the complexity of arrangement and the diverseness of objects

Although the aforementioned factors of gender and personality traits can be a predictor of modality use, the modality shifts over time presented in Section 5.5 should not be underestimated. Users show a strong shift towards speech use through the course of the experiment, without being able to pinpoint the exact reason for this. Maybe the operating wizard was just too good at understanding users' utterances or the fact that the other tasks (despite the selections discussed here) mainly involved speech use. Anyhow, it demonstrates the important role that a user's familiarity with a system plays in the way they interact with it, a fact not covered by any of the related work discussed in Section 2. As a consequence, any system that tries to anticipate a user's multimodal behavior should take the user's interaction history and its evolution into account whenever applicable.

7. SUMMARY AND OUTLOOK

We presented a Wizard of Oz study on the use of multiple input modalities during selections, as a common and prevalent task. The 53 subjects were unconstrained in their use of input modalities and could interact by using a touch screen, speech, pointing gestures, and any multimodal combination of these. The selections to be performed consisted of different apples on a dual touch screen. The goal was to find out more about the dependencies between the use of input modalities and influencing factors like the users' gender, their personality traits (NEO-FFI), their affinity towards technical devices (TA-EG), and the way tasks and selectable items are presented.

The most significant findings are related to the influence of gender, an influencing factor on modality use that is, to our knowledge, not well studied so far. While females almost only use the touch screen to perform selections, males are much more diverse. Not even half of their inputs are made by touch, about a third is done using speech, and nearly a fifth is performed using pointing gestures. For both genders, multimodal inputs are very rare for such easy selection tasks. Furthermore we demonstrate that NEO-FFI personality traits (for males) and TA-EG technology affinity scores (for females) can be predictors for modality use. As the observed shift in modality use over time shows, these findings must be put into perspective, when dealing with systems used over a longer period. If there is an interaction history of a specific user is available, it may be the best predictor of interaction behavior.

A surprisingly low influence is exerted by the way of selection presentation in our study. Only when the system uses speech output to tell the users that they have to select an object, they show a significant, but small increase in using speech, too. The observations presented in Section **??** however show, that presentation very well may have an influence on individual modalities (in this case speech).

Our findings can not only be helpful during the design of interactive computing systems, they can also be applied to user adaptive systems. While the assessment of user characteristics like personality traits is out of the scope of this paper, there are approaches of automatic recognition from verbal cues that could be used at runtime [10]. A fission process that arbitrates output modalities can be enhanced by knowledge about the gender or individual characteristics of the user to compose a more expedient system output. When a female user with a positive attitude operates a system, the system could avoid speech input by providing a graphical interface that facilitates touch input to play to the preferred input mode of women. Considering multi-user scenarios in a well-equipped environment, another benefit may result from intelligent device allocation for different user types. Within a multi-party interaction the system may try to address a male user via speech to offer an exclusively available touchpad for use to the female participant. Therefore such knowledge can also be used in some kind of resource allocation planning. Such knowledge can also be used in the fusion process of a system, of course. Knowing what type of user is currently performing inputs could help avoiding misunderstandings and resolving conflicts of multiple input modalities. When there is a conflicting input between a pointing gesture and a verbal utterance, this conflict could be resolved by relying on the speech input, if there is a male user with a high score in Openness, for example. The findings of this study could also be combined with machine learning techniques as described in [5] for multimodal integration patterns, to enhance robustness and reduce error rates of multimodal fusion. Furthermore, an intelligent scheduling of system resources could reduce processing time and memory consumption.

However, the presented study is just a small contribution in shedding light on the role the user and his individual characteristics play in influencing the way people interact with systems. The studied task of selection is just one of multiple basic interactions which are offered by today's systems and of which they are composed of. Further basic tasks that could be examined are confirmation, query, scrolling, entering values, and triggering actions to name only some. Additionally, there are a lot more characteristics of a user not explicitly focused in this study that could be of importance, e.g. age, expertise, level of education and so on.

The long-term goal of this research is to empirically measure the essential influencing factors on multimodal interaction during basic tasks, to lay the foundations for predicting user behavior in more complex scenarios and across different domains.

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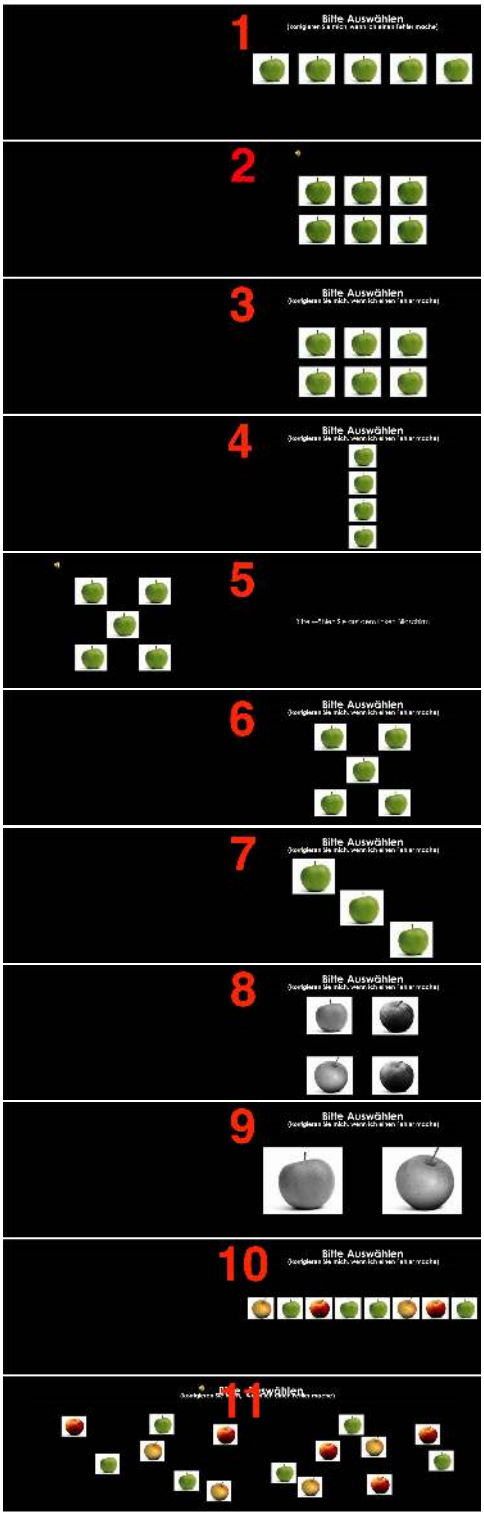
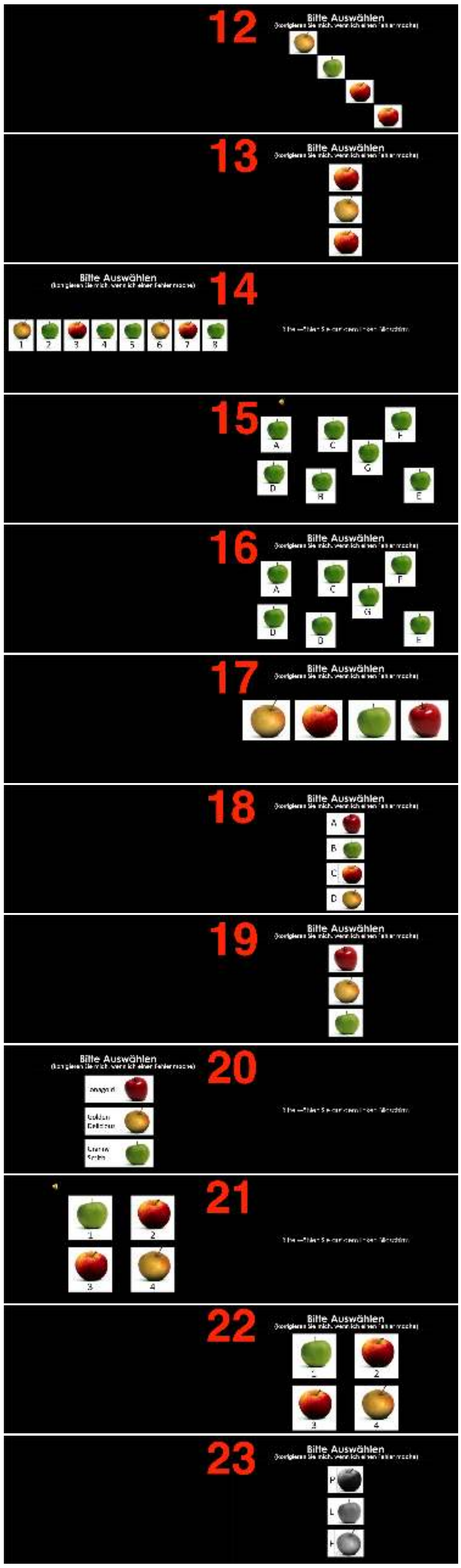
APPENDIX

A. SELECTION TASKS

The following figures show all selection tasks used in the study. The red numbering is only for the purpose of telling them apart and was not presented to the users.





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