That's not Norma(n/l)!
A Detailed Analysis of Midas Touch in Gaze-based Problem-solving

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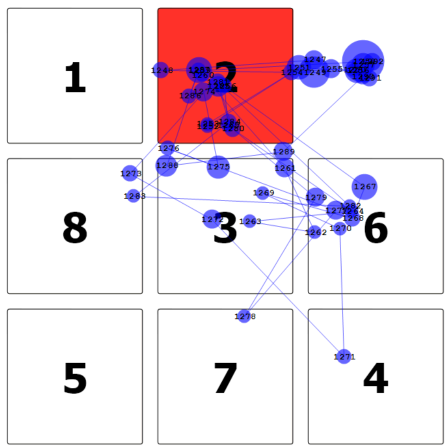

Figure 1: Gaze behavior during interaction error. The tile "2" moves to the right even though the user was not planning it. Gaze-path was not shown during real interaction.

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Abstract
Interaction error prevention needs to start from a good understanding of the context of an error. One of the central issues in gaze-interaction research is the suppression of the so-called Midas touch: the interface's incorrect evaluation of user gaze as a purposeful interaction command. We conduct a detailed analysis of numerous instances of these events during interactive problem-solving. By developing and applying an annotation scheme we present a taxonomy of the errors and remedial strategies users employ. We present the nuances, richness and development of the user behavior when dealing with the outcomes of the error, and uncover two major coping strategies. The knowledge will be used to design automatic error-prevention mechanisms for gaze-based interaction.

Author Keywords
intentions, errors, Midas touch, gaze

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies.

Introduction
One of the goals of user interface design is to create error-free interaction, which is a notoriously challenging task. Chapter 22 on Human Error and User-Interface

Design of the 1997 *Handbook of Human-Computer Interaction* contains an innocent but still valid quote related to interaction error: "*It is probably impossible to design systems in which people do not make errors*" [6].

If error-free interaction cannot be guaranteed by design, what are the ways to reduce human error? We propose to employ eye-tracking in its *passive monitoring function*, as a low-latency source of information about user intentions to commit an action.

Early detection of action or its prediction before it occurs are important for building more intelligent user interaction and can serve multiple purposes. For example, if a system is able to predict a sequence of actions leading to an unwanted configuration or an error state with low latency, adequate prevention mechanisms can be triggered. Similarly, if a non-intentional interaction is registered, an intelligent system can learn to ignore it automatically.

Error detection in interaction has been previously observed in EEG signals, e.g. [8, 2]. In this line of research, a typical brain activity associated with the user, becoming aware of error, is reflected in the EEG signals. Such a pattern occurs approximately 150 ms after the event and can be detected using off-the-shelf low-cost hardware with accuracies of about 60-80%. To our best knowledge, using gaze for detection of interaction errors has not been investigated so far.

In this research, we approach the design challenge by studying the details of gaze behaviors during interaction actions occurring when the user issues a command or provides input. In particular, we investigate the different types of errors users make while interacting with a problem-solving interface. We study the *patterns of visual attention* associated with different qualities of action.

Intentions, actions, and errors in gaze-based interaction

Every interaction with an interface consists, at least, of planning of an action, its implementation and evaluation of the outcomes [5]. A majority of user interaction requires perceptive and attentive acts of the user, because often at least one of planning, implementing, or evaluating an action happens through the means of visual modality. On the level of visual attention, the act of planning an interaction requires a user to consider available interactive options. The implementation of the action requires an active coordination of the primary interaction modality with attention. The evaluation of the outcomes requires mapping of the state of the interface and state of the world.

When interacting with user interfaces through the means of gaze, Midas touch [3] – the misinterpreted intention to interactive action fired by UI when a user merely looks at an element– introduces a disturbance in the action chain. This phenomena is illustrated in Figure 2.

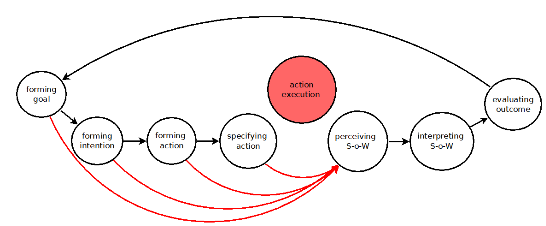


Figure 2: The consequences of Midas touch. Interruption or inadvertent interaction (in red) causes skipping the execution action and leads directly to corrections in state of the world (SoW). Inspired by [5].

An interaction error caused by Midas touch (MT) can unintentionally occur at any moment, but in particular it has large consequences during the planning activities [1]. The reasoning chain is broken and a user has to resort to correcting the error outcomes. As a result, user frustration increases and problem solving performance drops.

To characterize the user behavior around the occurrences of interaction error and to provide more knowledge about the particular circumstances of the errors and user reactions to them, we have rigorously analyzed the data from a gaze-based problem-solving interface. We discovered various types of strategies users develop when dealing with interaction errors, developed a taxonomy of these behaviors and use it to annotate 278 instances in which an interaction error occurred.

Our analysis uncovered that there exist several types of behaviors in response to Midas touch and that users develop strategies to deal with it. The characterization of these behaviors can in future be used for building intelligent gaze-based interfaces.

Method

During a replay of interactions with a gaze-based problem-solving interface, we noticed various types of activities taking place. For example, a Midas touch error was often corrected by some users, however, when a chain of errors occurred, the strategies differed.

The experimental dataset was collected during a study of Bednarik et al. [1], in which effects of various interaction modalities on problem-solving strategies were examined. Figure 1 shows a screenshot of the user interface. The 8Tile puzzle is a widely investigated paradigm in HCI employed for investigations of effects of operator costs on problem-solving strategies and interaction.

The goal of the user is to arrange the tiles from a starting shuffled configuration to a target organised order. In this particular instance of the 8Tile puzzle users were interacting with the problem entirely by the means of gaze. A one-second timer associated with each tile started to count down when a user continuously gazed at the tile. When the timer expired, the tile moved. To counter the problems with the noise in the gaze signal, very short interruptions were allowed during which the user's gaze could wonder outside the tile without the timer being reinitialised. Progress of the timer was indicated by increasing hue of the red color filling the tile.

The participants' gaze was recorded using a binocular Tobii ET 1750 eye-tracker with a sample rate 50Hz and an accuracy error around 0.5°. Gaze augmented recordings were exported using ClearView [7] and annotated in ELAN software [4].

In this paper, we analyzed data from participants with the proportion of Midas touch moves over 10% of all moves. Thus, two male and two female users who had normal or corrected to normal vision, in the age range of 23 to 52 ($M = 31.00$, $SD = 14.69$) were included. Table 1 describes the distributions of participants' overall moves and Midas touch moves.

Annotation and analysis

We started the annotation of the interaction data with the goal of identifying the segments in which an error happened. Upon realizing that there are in fact a variety of errors and associated user behaviors, we then employed an emergent coding technique, in which new categories were added and combined, as we observed more of the data. As a result, the final coding scheme was as follows (MT = Midas Touch):

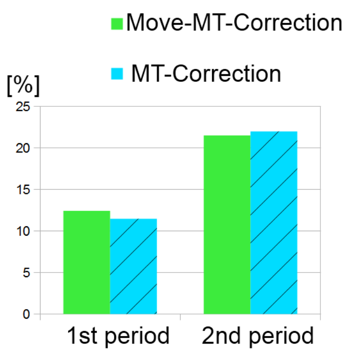


Figure 3: An overall distribution of *Move-MT-Correction* and *MT-Correction* in the first and the second game periods.

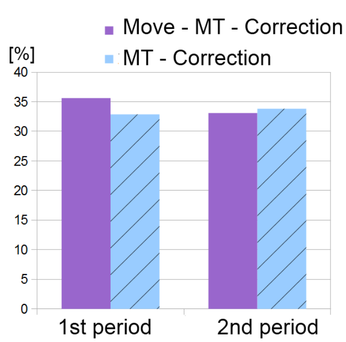


Figure 4: A proportion of error patterns (*Move-MT-Correction* and *MT-Correction*) in the first and the second game periods.

- *Move - MT - Correction* A sequence in which the participant performed a planned move, however, while checking the outcome of the action, an extra (Midas touch) move happened and returned the puzzle tile back to its original position. As a following action, the participant corrected this unintended move and returned the puzzle tile to the intended position.
- *Move - MT - Correction - MT - Correction* A case similar to the previous error pattern, where Midas touch occurred twice over the same puzzle tile.
- *Double MT - Double corrections* While planning or performing a move, a 'Midas touched' tile moved unintentionally. As a attempt of correction, another Midas touch instance caused another puzzle tile to move. As a consequence, the participant had to correct the tile moves in the reverse order.
- *MT - Correction* A participant was planning or trying to move a puzzle tile, when the UI performed an unintended move with another tile. As a following action, the participant corrected the Midas touched move to the prior puzzle tile configuration, and continued his previous activity.
- *MT - No correction* A participant was planning a game strategy while a puzzle tile unintentionally moved. The participant did not correct the move and included it in his planning strategy.

Further examples with gaze replay videos and participants' comments are presented in an online appendix[1].

The above-described taxonomy covers most of the observed error patterns. A deeper analysis of more complex patterns, their impact on participants' attention and strategy planning, is out of scope of this work-in-progress paper and will be studied in future work.

[1] http://cs.uef.fi/~hanav/chiAppendix.htm

Table 1: Study dataset.

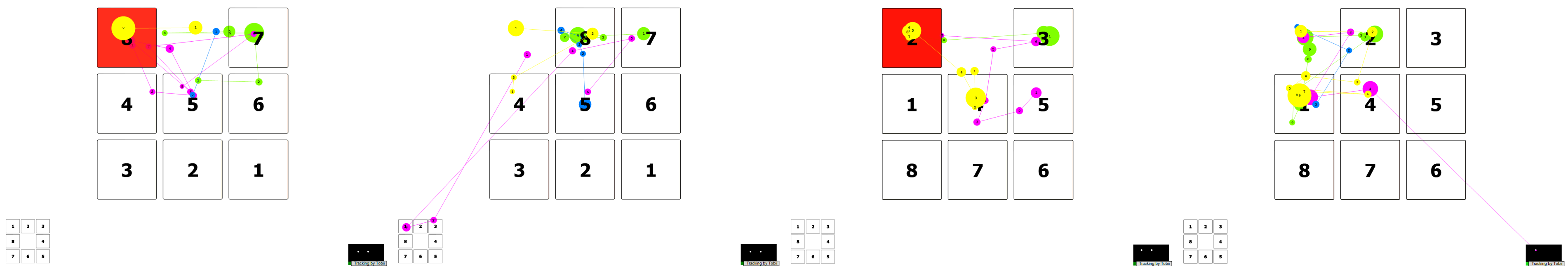
Participant	Tile move	Midas touch	Error rate [%]
1	366	44	12.02
2	654	78	11.93
3	357	77	21.57
4	454	79	17.40
Total count	1831	278	15.18
Mean	457.75	69.50	15.73
SD	137.96	17.02	4.66

To evaluate whether and how the strategies develop, when encountering an interaction error caused by Midas touch, we split each data file into two equal periods. Therefore, we could compute the proportions of various types of errors in the first and second half of the problem-solving.

Results

Table 2 shows a distribution of strategies associated with the occurrences of interaction errors due to Midas Touch. The two most-frequent behaviors were the sequences "Move-MT-Correction" and "MT-Correction" that summed up to 65% of all error-coping behaviors. About eight percent of the strategies involved those where the user did not correct the unintended move.

Figure 3 illustrates the overall distribution of the two main types of error patterns to the total number of errors occurring during the entire experiment. It is obvious that the overall number of these frequent errors increased in time. For example, of the total of 33.5% of "MT-Correction" first 11% happened during the first half



(a) Before a MT move **(b)** After a MT move **(c)** Before a correct move **(d)** After a correct move

Figure 5: Gaze patterns of four participants (displayed as four colours) during a Midas touch and a correct move. Figure 5a illustrates a situation *before* tile 8 unexpectedly moved (due to Midas touch) in comparison with a situation *after* the interaction error, see Figure 5b. A similar comparison is held in Figures 5c and 5d where the tile correctly moved on users' demand. All gaze plots show gaze data from approximately 2 seconds.

of problem-solving while the remaining two thirds (22.5% of the total number of error-coping behaviors) happened in the later half. Thus, it is safe to conclude that at the beginning there were fewer errors and the occurrence of errors increased toward the end.

Figure 4 demonstrates progressive error patterns during the game play; here, the proportion of the two most frequent patterns is compared only with regard to the number of errors within the associated half. We observe that the proportion of the errors remained more-or-less same regardless of the time. For example, the "Move-MT-Correction" sequence occurred as about every third error sequence at the beginning and at the end.

Finally, we examined the gaze patterns typically exhibited before and after an error occurred and compared those to normal patterns. These are visualized as gaze-plots in Figure 5. The visualizations show that participants need to stop problem-solving activities such as searching the space and instead they need to focus their attention to investigating the unexpected behavior of the interface.

Table 2: Frequency and proportions of error patterns in interaction.

Error pattern	Count	Proportion [%]
Move-MT-Correction	71	33.97
Move-MT-Correction-MT-Correction	8	3.83
Double MT-Double correction	9	4.31
MT-Correction	70	33.49
MT-No correction	16	8.13
Total	174	100

Discussion and Conclusions

Our long-term goal is to gain understanding of how visual attention and strategy planning develop and interact when facing complex error chains. We observed several types of strategies of how users deal with unexpected user interface behavior.

Our analysis shows that there are distinct incarnations of Midas touch in gaze-based problem solving and that users develop ways to counter the error. By developing and applying an annotation scheme we presented a taxonomy of the errors and the remedial strategies users employ.

However challenging to the problem-solving, Midas touch errors in interaction do not always necessary conclude into correction of the unwanted move. In several cases they have opened up new possibilities to the users to deal with the problem solving task.

Furthermore, the participants in our studies learned to overcome limitations and patiently found a way to deal with the specific challenges of gaze interaction. We have observed that several participants learned to ignore the Midas touch moves, continued in strategy planning and started correcting the Midas touch when they were sure about the following steps. Anecdotally, one participant exploited the behavior of the gaze-timer and learned how use Midas touch effect for intentional moves. Although she was told to focus on the puzzle tile to move it, she learned to move the tiles while switching between tiles.

We are planning to use this detailed knowledge in the design of more intelligent gaze-based interfaces. For example, in eye-typing and other dwell-time interaction, the detailed models of gaze-behavior can be used for detection of unintended moves.

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