Uninstructed Assessment of Episodic-like Memory in Humans With Especial Reference to Temporal Order

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Abstract

A key aspect of human episodic memory is its ability to process and reconstruct temporal information. Research on humans suggests the employment of mental time travel in memory for time. Since mental time travel is a phenomenal construct, which can only be assessed by verbal report, non-human animals are said to be stuck in time and thus, are unable to recall the time of an event. All experiments used in memory research on humans used instructions to model behavior. Conclusions drawn from these studies are neither directly transferable nor comparable to non-human-animals. In order to draw valid conclusions, considering the mental ability of non-human animals to place events in time, the comparability of the experimental design should be maximized. Aim of the present work is the development of such an experimental design. In three experiments we adapted a What-Where-When task, which focused on the temporal component, using pictorial material. Instructions were replaced by an associative learning paradigm, which guided participants through the task. Participants passed through three consecutive testing days, each consisting of an encoding, recognition, response and feedback phase. The picture sequences seen on the encoding phase of each Test day were supposed to be matched to their day of occurrence, using response buttons, which should be identified as temporal tags (´today´, ´yesterday´, ´two-days-ago´ and ´not seen in the encoding phase´). At the end of each Test day, participants were asked to write down their proposition about task´s requirements. While the majority of participants failed to verbalize task requirements in a verbal disclosure, our implicit data showed that behavioral performance was indicative for task identification. Furthermore, implicit behavioral performance even improved remarkably, when task difficulty was reduced and when the emphasis on the temporal aspect of the task was increased. In conclusion, associative learning seems to be a promising non-verbal method to assess the retrieval of temporal information from episodic-like memory.

Zusammenfassung

Ein Hauptmerkmal des menschlichen episodischen Gedächtnisses ist die Verarbeitung und Rekonstruktion zeitlicher Information. Gedächtnisforschung am Menschen legt die Beteiligung der mentalen Zeitreise am Rekonstruktionsprozess nahe. Der Einsatz dieses phänomenalen Konstrukts lässt sich allerdings nur durch die verbale Auskunft erfassen. Da Tieren jedoch die verbale Kommunikationsfähigkeit fehlt, wird ihnen die zeitliche Einordnung erlebter Ereignissen aberkannt. Dabei bedient sich die vergleichende Gedächtnisforschung am Menschen der verbalen Instruktion und steuert damit nicht nur das Verhalten, sondern reduziert auch die Übertragbarkeit und Vergleichbarkeit der Befunde auf andere Spezies. Allerdings können valide Rückschlüsse nur dann gezogen werden, wenn die Vergleichbarkeit der angewandten experimentellen Methoden gegeben ist. Ziel dieser Arbeit ist die Entwicklung eines solchen non-verbalen Ansatzes. In drei aufeinander aufbauenden Experimenten implementierten wir eine Was-Wo-Wann-Aufgabe, mit erhöhtem Fokus auf den zeitlichen Aspekt. Instruktionen wurden durch assoziatives Lernen ersetzt. Die Teilnehmer durchliefen an drei aufeinander folgenden Tagen, jeweils eine Enkodierungs-, Rekognitions-, Antwort- und Feedbackphase. Die Bildersequenzen waren, unter Bedienung von Antwortknöpfen, dem entsprechenden Tag ihres Erscheinens in der Enkodierungsphase zuzuordnen. Dabei waren die Antwortknöpfe als zeitliche Marker (heute, gestern, vorgestern, nicht in der Enkodierungsphase erschienen) zu identifizieren. Am Ende jedes Testtages gaben die Teilnehmer an, welche Aufgabenanforderungen sie vermuteten. Während die Aufgabenanforderungen nicht verbalisiert werden konnten, deuten die Verhaltensdaten auf ihre Identifikation hin. Darüber hinaus zeigte sich eine deutliche Leistungssteigerung durch die Reduktion der Aufgabenschwierigkeit und der Betonung des zeitlichen Aspektes der Aufgabe. Schlussendlich scheint das assoziative Lernen eine vielversprechende Methode zu sein, um non-verbal zeitliche Information aus dem episodischen Gedächtnis zu erheben.

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1. Introduction

Time travel is a concept which has fascinated humans for decades. It inspired them to write stories about time-traveling adventures like ´Back to the Future´ in which Marty Mc Fly moved to the past, using a time machine and changed events, provoking changes in his own present. In the 20th century Albert Einstein developed the theory of special relativity. This theory states that, time slows down when an object reaches speeds close to that of light. If it travels faster than light, confines of time will not apply and traveling to the future will be possible (Einstein, 1905). While many physicists today agree on the possibility of time travel to the future, traveling into the past remains controversial. But behind the ´real´ world's physics there is a unique universe in which time travel backward and forward is possible without constraints. In this universe it is possible to travel forward in time to an imaginary distant future, in order to anticipate future needs or imagine the outcome of present goals, which should make up our future life. It allows us also to move from one memory in the past to another backward in time to the episodes, which make up our biography. This universe exists in the human mind and is termed episodic memory.

1.1 History of episodic memory

The term episodic memory was introduced by Tulving (1972). He subdivided declarative memory into two fundamentally different memory systems: semantic and episodic memory. Differences encompassed the nature, reference and retrieval of the stored information. Semantic memory was characterized as memory for facts and general knowledge and as being essential for the use of language. Inputs are stored free of context and with cognitive reference. Information from semantic memory can be retrieved by inferential reasoning without changing the content of the retrieved information. Episodic memory was referred to the storage of personally experienced events. These are temporally dated and feature temporal-spatial relationships and autobiographical reference to other events from the own past. Retrieval from episodic memory is only possible if the relevant episode has been encoded earlier. The retrieval process acts as additional input into episodic memory and induces changes to the contents. In the 70s Tulving´s distinction between these two systems was heuristic in nature and did not encompass structural or functional (operations) separation. He pointed out the optional interaction between these systems and that mutual influence was not obligatory.

The functional distinction between semantic and episodic memory was first postulated in ´Elements of episodic memory´. Arguments for differences were based on information processing, operations and applications. Operational differences encompassed among others, the mental state accompanying retrieval from both systems. While retrieved information from semantic memory represents impersonal experience limited to the present, remembered events are characterized as personal and belonging to the own history. Recollected events are accompanied by the conscious awareness that these are re-experienced here and now (Tulving, 1983). This definition was broadened by specifying the nature of conscious awareness underlying the retrieval from both systems. The retrieval from semantic memory was referred to as noetic consciousness, whereas recollection from episodic memory is accompanied by a special kind of consciousness, an autonoetic one.

Noetic consciousness involves internal representations of events and objects. It mediates the awareness of physically absent events and objects and allows cognitive operations to access them. It is characterized by the absence of self-reference. Autonoetic consciousness involves the self and is essential for remembering personally experienced events from the past. It mediates the awareness that this event is part of one´s own history (Tulving, 1985a).

Some years later, Tulving (1993) posited that episodic information concerns the self´s experience embedded in the subjective temporal and spatial context. In contrast semantic information concerns the relations of objects to the world. Moreover episodic memory is the only memory system enabling its owner to remember the temporal organization of non-related events and, most notably, to mental time travel into the personal past as well as the future. Furthermore, a hierarchical relationship between semantic and episodic memory was assumed. It postulated that semantic memory can operate independently of episodic memory, while the operation of episodic memory remains dependent on semantic memory (Tulving, 1993). In a redefinition Tulving (2001) revised and modified episodic memory, to include to the content of the memories phenomenal constructs which constitute the essence of episodic memory, the subjective conscious experience *(autonoetic awareness)* and *subjectively sensed time* (*chronesthesia*). Chronesthesia is the specific kind of consciousness facilitating the awareness of subjective time in which one exists. The *sense of subjective time* enables the owner of an episodic memory, to mentally travel back to a specific point in time and re-experience, through *autonoetic awareness*, a particular event from the subjective history. Chronesthesia and autonoetic awareness are closely related. Both imply the awareness of the self in time, but in chronesthesia the focus is on the awareness of subjective time, whereas autonoetic consciousness emphasizes the awareness of the self (Tulving, 2002).

Biological support for the theoretical distinction between episodic and semantic memory came from brain damage and functional brain imaging studies. Neuropsychological studies of the consequences of brain injury revealed asymmetric impairment of declarative memory performance. These studies encompassed cases with selective impairment of episodic memory performance (Levine et al., 1998; Markowitsch & Staniloiu, 2013; Tulving, Moscovitch, Schacter, & McLachlan, 1988; Vargha Khadem et al., 1997) and those with selective semantic amnesia while episodic memory was spared (Grossi, Trojano, Grasso, & Orsini, 1988). Consistently functional brain imaging studies found differential brain activation patterns while performing a semantic vs. episodic memory task (Huijbers et al., 2012; Nyberg, Kim, Habib, Levine, & Tulving, 2010; Slotnick, 2013; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994; Viard et al., 2011).

1.2 History of Episodic-Like Memory

Tulving (2001) and Tulving and Markowitsch (1998) declared episodic memory to be uniquely human implying that animals cannot remember the content and spatial location of an event. But at the time of publication, evidence from comparative psychologist studies already indicated that food hoarding birds remember where they hide a particular type of food (Kamil & Balda, 1985, 1990; Sherry & Sherrt, 1982; Shettleworth & Krebs, 1982). Driven by these findings, Clayton and Dickinson (1998) examined episodic memory in birds. They split the behavioral definition of episodic memory to three distinct features: Information about the content of an event `What´, the spatial location ´Where´ and the time in which the event occurred ´When´. They could demonstrate that scrub jays remembered what kind of food was cached where and notably when or how long ago. The possibility that scrub jays relied on the familiarity of the location of the trays, relative preference of the food, or on remembering a single component was excluded (Clayton & Dickinson, 1999a, 1999b; Clayton, Dickinson, & Yu, 2001). Subsequent follow-up studies confirmed that scrub jays not only remember where they hide a specific kind of food and when, but also integrated new information, gained in the retention interval in the previous caching episode (Clayton & Dickinson, 1998, 1999a, 1999b; Clayton, Dickinson, et al., 2001; Clayton, Yu, & Dickinson, 2003). Furthermore, they could anticipate future needs and adapt their caching behavior to their potential future needs (Clayton, Bussey, & Dickinson, 2003; Correia, Dickinson, & Clayton, 2007).

Because these findings fulfill only the behavioral criteria of episodic memory, the authors referred their findings to a ´episodic-like´ memory system, similar to human episodic memory but open about the nature of subjective representation. Evidence for content, spatial and temporal memory was further reported in hummingbirds (Flores-Abreu, Hurly, & Healy, 2012; Henderson, Hurly, Bateson, & Healy, 2006), chickadees (Feeney, Roberts, & Sherry, 2009, 2011a, 2011b), magpies

(Zinkivskay, Nazir, & Smulders, 2009), clark's nutcracker (Gould, Ort, & Kamil, 2012), pigeons (Petruso, Fuchs, & Bingman, 2007; Skov-Rackette, Miller, & Shettleworth, 2006; Zentall, Clement, Bhatt, & Allen, 2001) and in non-food storing songbirds (H. J. Bischof, Lieshoff, & Watanabe, 2006).

Since episodic-like memory could be found in birds it was expected to be present in other animals. Efforts were extended to examine other species and revealed episodic-like memory in rodents (Bird, Roberts, Abroms, Kit, & Crupi, 2003) and in a subdivision of the non-human higher primates: the old world cattarrhini (orangutans, gorillas, chimpanzees, rhesus monkey). The first author to investigate episodic-like memory abilities in chimpanzees were E. W. Menzel (1973) & C. Menzel (1999)

1.3 Assessing episodic memory in humans

Various tests have been designed to assess episodic memory in humans. Laboratory tests can be implemented by using a recall or recognition task, in which participants are presented with a list of items and, after a delay, are asked to recall or recognize these items. In a free recall task items are to be recalled either without considering their order or by regarding their position in the list (serial recall). In a cued recall task participants are given an item as a cue. This item can be the semantic category of the item to be retrieved or an associated item pair from the list. Recognition memory tasks can be either free (yes-no) or forced choice. In the first type, participants affirm or deny the appearance of an item in the list and in the second, they are presented with two items and asked to choose the one that appeared most recently in the list. Further tests are ‘frequency estimation tasks’ and ‘recency judgment tasks’. These tests were expanded with the refinement of the definition of episodic memory.

In 1972 when the distinction between episodic and semantic memory was heuristic in nature, support came from case studies of amnestic persons, who suffered impairment of either episodic or semantic memory system. Impairment of episodic memory was assessed using the classic list learning paradigm, in terms of learning and then recognizing word items in a list followed by new-old-judgments (Tulving, 1972). At that time, Atkinson and Juola (1971) proposed the *two component memory model* assuming that recognition judgments are based on two different memory processes, familiarity and recollection. These processes occur subsequently, where recollection represents the demanding exhausting research path, which is activated after familiarity fails. Another model addressed that familiarity and recollection can also act parallel, with recollection being the slower and familiarity the faster searching path (Eichenbaum, Yonelinas, & Ranganath, 2007; Mandler, 1980).

In elements of episodic memory, Tulving rectified his assumption since the retrieval of words comprised only the What-component and not the context of the encoding situation (Tulving, 1984). Inspired by the two component theory, he developed the ´Remember-Know´ technique, which was the first in assessing not only behavioral criteria but also the subjective experience accompanying the retrieval process. Participants were instructed to recognize list items and further judge these as being familiar and accompanied by the feeling of knowing (Know-Judgment) or remembered including contextual details (Remember-Judgement) (Tulving, 1985b). The remember-know-paradigm targets not only the verbal disclosure but also the introspective ability and report of the subject being tested, excluding aphasic patients and prelingual children. Moreover, 'Remember-Know-Judgments' rely on subjective experience and are difficult to verify using objective criteria (Dunn, 2004; Wixted, 2007).

Episodic memory assessment tools used in the clinic include the ´Montreal cognitive assessment´ (Nasreddine et al., 2005), the ´Blessed dementia information–memory–concentration test (Blessed, Tomlinso, & Roth, 1968), the ´Mini-Cog´ (Borson, Scanlan, Brush, Vitaliano, & Dokmak, 2000), the ´Mini-mental state´ examination (Folstein, Folstein, & McHugh, 1975), the 7-min screen (Solomon et al., 1998), the ′Three words-three shapes′ memory test (Weintraub et al., 2000) and the ′Word list memory test′ of the Consortium to Establish a Registry for Alzheimer's Disease (Welsh, Butters, Hughes, Mohs, & Heyman, 1992)

Both laboratory and clinical tasks assess either the purely behavioral criteria or combine these with behavioral markers underlying mental states such as recollection. Both cannot make predictions about real life functions. Because it is difficult to test each subject or patient in a naturalistic environment, virtual reality applications focusing on episodic memory functions have been developed, tested and validated. The virtual equipment consists of a computer-generated 3-D model of an artificial environment which is explored by the participant. This is followed by a free recall or recognition test of certain objects and scenes from the virtual town encoded previously (Burgess, Becker, King, & O'Keefe, 2001; Parsons & Rizzo, 2008; Plancher, Barra, Orriols, & Piolino, 2013; Plancher, Gyselinck, Nicolas, & Piolino, 2010; Plancher, Nicolas, & Piolino, 2008; Sauzeon et al., 2012). The aim of these applications is to create experiments closer to daily life, while retaining experimental control of the environment.

1.4 Assessing episodic-like memory in non-human animals

Assessing episodic memory in non-human animals can be implemented by means of behavioral criteria only. The phenomenal constructs require not only introspection but presume also and primarily the ability to verbally report this experience. However, since it is understood that non-human animals do not possess this kind of comprehension ability, the search for objectively defined behavioral markers, underlying these constructs, is necessary. An overview of the paradigms developed to date is provided in the chapter below.

1.4.1 Food-Caching-Paradigm

Clayton and Dickinson (1998) laid the foundation for a ´recognition memory paradigm´, which in the future should be used in most of the designs testing episodic-like-memory in non-human-animals, the What-Where-When-paradigm (WWW-paradigm). They examined episodic memory in birds by making use of their ecological food caching behavior. Scrub jays passed through two caching trials separated by a short (4-hr) and a long (124-hr) inter trial interval (When). In each trial they were allowed to cache either wax-worms or peanuts (What) in a sand-filled storage tray (Where). While wax-worms perish after long retention intervals, peanuts did not. After a retention interval of 4 hours they were allowed to recover the cached food. The authors found that after short inter trial interval (4-hr) wax-worms were first recovered, whereas, after long intervals (124-hr), peanuts were first recovered. This behavioral pattern was interpreted as indication for knowledge of the location of the two different food types regarding their storability and thus regarding the time it was baited.

Bird et al. (2003) adapted the WWW-paradigm on rats. Rats were allowed to hide two food items (Cheese, Pretzels) in an eight arm radial maze. After a retention interval of either 1 or 25 hours they were returned to the maze. The extent to which rats visited baited locations was recorded. In the preceding five experiments rats demonstrated discrimination of the kind of food and its location. In the sixth temporal information had to be additionally remembered. Even though rats could remember what and where they were not sensitive to the temporal component (when) of episodic-like memory.

Hampton, Hampstead, and Murray (2005) implemented the food caching paradigm in an open field. Rhesus monkeys passed through a study and two test phases which were separated by a short (1-hour) and a long (25-hours) retention interval. In the study phase monkeys would find a preferred and a less preferred reward in two out of three baiting locations. After long but not short retention intervals the preferred food was replaced by a distasteful food. Rhesus monkeys remembered the location of the foods, but they failed to integrate the temporal information to their search strategy.

1.4.2 Odor recognition task

Fortin, Agster, and Eichenbaum (2002) developed a task to test memory for sequential order in rats. Rats sampled five randomly selected scents mixed with sand in a cup with an inter-trial interval of 2.5 minutes. In order to ensure that they smelled the odor of the scents, rats were rewarded for digging in the sand. In the probe trial rats were presented each time with two of the five scents in a randomized order and were rewarded for selecting the odor that appeared earlier in the sequence. Rats performed with high accuracy (80%), demonstrating sequential order memory.

Recently, Templer and Hampton (2013) examined the cognitive mechanisms underlying memory for temporal order by implementing an order recognition task with pictures. Rhesus monkeys were shown a list of five pictures chosen randomly out of 6000. In the probe trial, 2 pictures from this list were presented, and rhesus monkeys were rewarded for choosing the one that appeared earlier in the list. Findings revealed that the tested monkeys were able to recognize the temporal order of the pictures.

1.4.3 Novelty preference Paradigm

Most of the episodic-like memory-tasks require extensive training and facilitate semantic rather than episodic recall. A single exploration task combining object, spatial and temporal order memory, which is based on the novelty preference paradigm was designed by Dere, Huston, and Silva (2005b). Mice passed through two ´sample´ and one ´test´ trial. In the first sample trial, four copies of a novel object were explored. Following a delay of 50 minutes the second sample trial was initiated in which the mice could explore 4 additional copies of a novel object, which were placed in different locations. 50 minutes later, the mice undertook the test trial in which two copies of the object from the first sample trial and two from sample trial 2 were presented with an object of the first sample trial being displaced to a location which had not been previously encountered. The time mice spent exploring an objects was recorded. It revealed that mice spent more time exploring the spatially displaced object relative to a stationary object. Thus mice were sensitive not only to the objects and their spatial location but also to the temporal order in which they occurred. These findings were replicated in subsequent investigations which also tested rats (Dere, Huston, & Silva, 2005a; Dere, Kart-Teke, Huston, & Silva, 2006; Eacott & Easton, 2010; Eacott, Easton, & Zinkivskay, 2005; Eacott & Norman, 2004; Eichenbaum, Fortin, Ergorul, Wright, & Agster, 2005).

1.4.4 Delayed matching to sample Task

Hoffman, Beran, and Washburn (2009) examined WWW-memory in rhesus monkeys using a computerized delayed matching to sample task with pictorial materials. In the identity task, monkeys were required to select the picture that had been previously shown. In the spatial task, the location of the presented picture was to be selected. In the temporal task, monkeys had to select the symbol that was associated with the retention interval (1 vs. 10 s). They found evidence that monkeys integrated the ´What´, ´Where´ and ´When´ information in working memory.

1.4.5 What-Where-Which

A new approach considering the context of an event instead of the when-component was developed and tested on rats (Eacott & Norman, 2004). Rats were allowed to run through two exposure phases in an open field, in which the same two objects (Object A & Object B) were presented. In each exposure phase the color of the open field (Context 1 & Context 2) and the location of the objects were varied. In the test-phase the open field was configured either to context 1 or 2 and two additional copies of either object A or B were added. The time the rats spent exploring each of the objects was registered. Rats spent more time exploring familiar objects, displaced to another location in a different context, displaying memory for the spatial configuration of specific objects as well as the context in which they appeared.

1.5 Assessing episodic-like memory in humans

Several non-verbal behavioral tests for episodic memory have been adapted and implemented on humans. Some test designs aimed to identify a non-verbal behavioral response to assess episodic-like memory performance, others focused on understanding the brain mechanism underlying the particular behavioral features (what, where an when), while others examined whether humans use episodic memory to solve a WWW-task.

Since the WWW-paradigm is well established in the comparative field of psychology, Pause, Jungbluth, Adolph, Pietrowsky, and Dere (2010) developed a paradigm, in which they experimentally induced episodic memories for unique events by manipulating the spatio-temporal configuration of visual stimuli. Episodic memories were measured using verbal ratings and non-verbal motor responses. Participants passed through 4 sessions separated by approximately 24 hours. The first two were acquisition trials, the third a test trial and the fourth a recollection test. In each of the acquisition trials participants were presented with 9 quadrants and asked to explore these by pushing the corresponding button on the keyboard. One stimulus out of a pair belonging to a specific category was hidden behind 4 of 8 quadrants. During the test trial 2 stimuli from the first and 2 from the second acquisition trial were presented at familiar and new quadrants. In the first three sessions participants were instructed to remember the type and position of each of the visual stimuli. In the recollection test, participants were asked to verbally specify in which trial they had seen a specific visual stimulus and at what place. The authors found that participants were able to recollect the spatio-temporal (Where, When) context of a specific stimulus (What) and that their performance correlated with the exploratory button presses to each of the four quadrants containing this stimulus. They concluded that exploratory button presses can serve as a correlate for episodic memory performance. The paradigm of Pause et al. thus focused on assessing the three features What-Where-When in an integrated manner.

Babb and Johnson (2010) separately tested the What-Where-When features using unique visual scenes, containing furniture or various objects in different arrangements. In each of three blocks, 20 images were shown. In the What-condition, participants were presented one of the previously seen images with a missing object and asked to recall the removed object. Hereafter, two objects appeared on the screen, the target object and a familiar object, and participants were asked to choose the missing object. In the ´Where´ condition, a scene in which the target object was displaced appeared next to the original and participants were asked to identify the original scene. In the ´When´ condition, two previously seen scenes were presented and participants asked to judge which scene appeared earlier in the sequence of pictures. The authors found that participants performed better in the ´What´- than in the ´Where´- and ´When´ condition, even though performance in all three conditions was above chance. They concluded that their test design is qualified for use in the comparative study of animals to test, independently, identity, source and temporal memory.

Holland and Smulders (2011) asked whether humans use episodic memory to solve a What-Where-When task. They queried the assumption that the well-established WWW-paradigm does test episodic-like memory, since it required the active encoding of information, which, in turns, leads to storage in semantic memory. The authors designed a WWW- task resembling the food caching paradigm of Clayton and Dickinson (2001). Participants were assigned to an active and passive encoding condition. On each of two subsequent days (When), participants were allowed to hide two coin types (What), in different locations in a living room (Where). In the active condition, participants were instructed to memorize the WWW- information. In the passive one, they were told that they were hiding the coins for another subject. On day3, they were asked to recall where they hid which kind of coin on which day. Additionally, they received a questionnaire with unexpected questions about the context of the hiding episode, resembling a real episodic test. The authors found that the performance of the participants in the active treatment was slightly better than those of the passive treatment. Furthermore, performance on the questionnaire significantly predicted the performance on the WWW-task and most of the participants reported using mental time travel for recall. Holland and Smulders inferred that participants use episodic memory to solve the WWW-Task. One concern in this design is that it was based on free recall and, as such, not comparable to the experiments used with animals. Another is that ratings of the subjective state could not be directly assigned to the performance of the participants.

Easton, Webster, and Eacott (2012) considered these criticism and examined whether episodic-like-memory-tasks require conscious recollection. Human participants undertook two kinds of episodic memory task, a 'What-Where-When' and a 'What-Where-Which' recognition task. Two slides were sequentially presented. Each slide consisted of the same nine items in one of nine different locations. The background in these slides was varied. Following the second slide, participants were instructed to answer three different kinds of questions, what (Which symbol have you seen before?), What-Where-When (On which slide did you see this symbol in this particular location?) and What-Where-Which (On which background did you see this symbol in this location?). For each question participants were asked to state the experience accompanying their answer. Results from the What-Where-Which-task indicated that episodic-like memory recognition tasks just as episodic memory recognition tasks require recollection for accurate performance. In contrast, the results of the What-Where-When task revealed that participants do not always rely on recollection.

However, some of the above listed studies mainly assessed short term rather than long term recognition and in most of these studies the temporal component was not clearly operationalized, even though the special relationship of episodic memory to time was emphasized in all definitions (Tulving, 1972, 1983, 1993, 2001, 2002, 2005).

1.6 Temporal component in episodic memory

The temporal component was initially defined as being the marker to date events (Tulving, 1972). Extending the definition, it was postulated that episodic memory is organized by the temporal order in which the events occur, centering again on the temporal relationship between these events (Tulving, 1983). In subsequent articles this concept was modified to incorporate a sense of subjective time, moving away from a specific and instrumental temporal organization of the episodic memory toward a phenomenal construct, the mental time travel through subjective time and finally to the construct of chronesthesia (Tulving, 1993, 2001, 2002, 2005; Tulving & Kim, 2007). Mental time travel refers to the mental ability to travel from a point in the present back into the past in order to reconstruct personally experienced events or forward into the future to construct possible events and anticipate future needs (Suddendorf & Corballis, 1997). Chronesthesia is the specific kind of consciousness facilitating the awareness of subjective time in which one exists.

Episodic memory is said to be the only memory system allowing its owner to mentally travel in subjective time and consciously re-experience past events or project oneself into the one´s personal future in order to anticipate or plan future needs (Tulving, 2005). The way humans place events in time is important for our understanding of the episodic memory system and since the temporal component is one of its main features, there have been a number of varying approaches to define the kind of temporal information stored.

Over a period of six years, Wagenaar (1986) studied the recall of 2400 events from his daily life, by means of noting what, where, when the events happened and who was involved. He used a cued-recall-paradigm in which one of the recorded components was given as a cue while the other three were to be recalled. He found that the ´What-cue´ was most effective in facilitating recall while ´When-cues´ were least effective. He proposed that temporal information in episodic memory is stored in tags, which are not specific enough for successful retrieval.

Friedman (1993, 2004, 2007) postulated that the temporal context of an event is not automatically encoded and stored but instead is actively reconstructed by relating this event to three different kinds of temporal information: Temporal location, temporal distance and temporal order information. Temporal location information is based on conventional (clocks, calendars), natural (season, day or night) or personal (graduation, marriage) time. Temporal distance information is the elapsed time between the encoding and retrieval of the particular event, such that human use the strength of memory trace, or estimate the time that has passed since the event occurred, to retrieve the temporal context of this event. However, distance information is coded in conventional time unites (a year ago, within the past week etc.), making the distinction between temporal location and distance difficult. Temporal order information is built by the formation of before-after-relationships between events, using different events as anchors. Humans can employ three kinds of temporal information (Janssen, Chessa, & Murre, 2006). Laboratory studies of episodic memory use short retention intervals (seconds, minutes, hours), which may prohibit the use of temporal location or distance information by retrieval. Participants can rely only on temporal order as a retrieval cue. Longer retention intervals allow the use of conventional time patterns, giving participants the possibility to rely upon location and distance information.

In studies of episodic-like memory on humans a variation of short (Babb & Johnson, 2010; Easton et al., 2012) and long (Holland & Smulders, 2011; Pause et al., 2010) retention intervals were used. Even though Babb and Johnson (2010) and Easton et al. (2012), both used short retention intervals in their study design, the first research group found evidence for temporal encoding and the second group did not. The operationalization of the temporal component differed between both studies. In the first participants were asked to make ´recency´ judgments and they could make use of temporal order for retrieval. In Easton et al. (2012) they were asked to term the temporal context using conventional time patterns, without having the possibility to use these patterns as retrieval cue. In the studies using long retention intervals, these cues were confounded, since participants could rely on temporal order as well as on conventional time patterns to recall the associated time. The missing precision in operationalizing the temporal component in human studies of episodic or episodic-like memory is also found in the comparative field of studies.

1.7 Temporal component in episodic-like memory

The discordance in temporal timing mechanism in episodic memory was also reflected in animal models. The sense of subjective time was defined to be a premise for mental time travel and thus for the property of an episodic memory. This ability was declared to be uniquely human due to the lack of evidence that animals even think about subjective time (Tulving, 2001; Tulving & Markowitsch, 1998). Many researcher share the assumption that animals are stuck in time and cannot reconstruct past events or anticipate the future (Bischof-Köhler, 1985; N. Bischof, 1978; Suddendorf, 2013; Suddendorf & Corballis, 1997, 2007). This assumption was questioned by studies on various animal species that provided behavioral markers for this temporal sense.

In some paradigms 'When' was defined as the ability to track time (Clayton, Bussey, et al., 2003; Clayton & Dickinson, 1998; Clayton, Yu, et al., 2003; Hampton et al., 2005; Martin-Ordas, Haun, Colmenares, & Call, 2010; Roberts et al., 2008), in others, 'When' was ascribed to the ability to remember absolute time (Zhou & Crystal, 2009) whilst in others, 'When' was operationalized as the temporal order of the events (Dere et al., 2005b; Dere et al., 2006; Eacott & Easton, 2010; Eichenbaum & Fortin, 2003; Eichenbaum et al., 2005; Pause et al., 2010).

There is a lack of agreement on how to define the temporal component. Roberts et al. (2008) criticized that the temporal cues (how long ago and when) used in episodic-like memory studies on animals are confounded and promoted the necessity for a finer operationalization of the temporal component, while controlling confounding.

1.7.1 Elapsed time

In a rodent model of episodic-like memory Babb and Crystal (2005) defined the when component as the elapsed time (1 h vs. 25 h) between the study and the test phase. For control, the test phase was conducted at the same time of the day after both retention intervals (RIs). Lithium chloride treatment was given during the long retention interval but not during the short one. Rats visited the location baited with chocolate after short retention intervals and avoided them after long RIs. This discrimination performance was not based on absolute timing but on elapsed time. Using Babb and Crystal´s version of the WWW- task in the radial maze, Robert (2008) forced rats to use time of the day by making ´how long ago´ cues irrelevant. He found that performance was under 'chance level' when rats could not use the ´how long ago´ cue, suggesting that they do not use absolute time cues. He postulated that rats discriminate events by estimating the elapsed time between the study and the test phase and do not assign events to a framework in the past, using absolute timing.

1.7.2 Absolute timing

Zhou and Crystal (2009) examined whether rats remember the location of a certain food type (chow or chocolate) relying on the time of the day it has been previously encountered in (morning or afternoon). While chow never replenished in the previously encountered location, the availability of chocolate in the baited location was dependent on the time of the day it had been encountered. In order to avoid confounds of the when component they controlled for elapsed time, by using a constant retention interval between the study and test phase in the morning and in the afternoon. They could discount the findings of Roberts et al. (2008) and showed that rats relied on ´time of the day´ as a cue, even when the cue ´how long ago´ was made irrelevant.

1.7.3 Temporal Order

The discrimination of order represents a feature of episodic memory, that can be assessed in non-human animals (Eichenbaum et al., 2005). Fortin et al. (2002) suggested that the successive presentation of two or more distinct events, would qualify for the operationalization of the ´When´ component. A modified version of the novelty preference paradigm, in which 'When' was defined as the temporal order in which two different objects were presented in the past, was implemented on rats. This revealed that rats recognized objects they had previously explored, during separate trials, and remembered the order in which these had been presented (Dere et al., 2005a, 2005b; Dere et al., 2006).

1.8 Summary

Episodic memory is currently defined using phenomenal constructs such as the self, chronesthesia, autonoetic awareness and mental time travel and often framed to be uniquely human. Episodic-like memory is the term used to label an equivalent memory system in animals. Its definition fulfills only the behavioral criteria of episodic memory, since the assessment of the phenomenal constructs depends on language and comprehension abilities, which many species do not seem to possess. Comparative psychologists have long been examining episodic performance of non-human animals, by means of distinguishing the spatio-temporal context of different events (What-Where-When-Paradigm). For this purpose many experimental designs have been developed. While the identity and source component is commonly assessed in all designs, differences encompass the 'When' component, which is either operationalized as elapsed time, absolute timing or temporal order or alternatively replaced by the context of an event (What-Where-Which-Paradigm).

Comparative research revealed inconsistent findings considering the temporal component, which seems to be a function of the tested species. Evidence for temporal encoding, that resembles time tagging theories, was reported in scrub jays, humming birds, mice and rats. No evidence could be found in chimpanzees, crested gibbons, gorillas, orangutans and rhesus monkeys. Episodic-like memory was also assessed in humans using the WWW-paradigm and revealed the involvement of episodic memory in solving these tasks. However, some of these designs focused mainly on assessing short term rather than long term recognition and in most of these studies the temporal cues were confounded. None did report whether they follow a time tagging or reconstruction theory and thus, the type of temporal cue, participants used to solve the task was not clearly operationalized. Another constraint is that all these studies claim to be non-verbal, but they still use instructions to model behavior. Because of these methodological confounds, the conclusions drawn from these studies are neither directly transferable nor comparable to non-human-animals.

Recent research on declarative memory, suggests that language might have contributed to the evolution of semantic and episodic memory, but that operations of these memory systems are still independent of language or different symbolic systems (Tulving, 2005). This assertion allows the assumption, that encoding and retrieval from episodic memory should be possible without the explicit use of language.

1.9 Thesis aim

Out of the limitations mentioned in the summary, the necessity arises to develop an episodic-like memory paradigm, which considers two points: Waiving instructions and verbal material for comparability and precisely defining and controlling the temporal cues used during retrieval. Since research on human episodic memory could not find evidence for an automatic encoding of time, the reconstruction approach should be followed. The temporal cue used should be defined as location, distance or order based.

Aim of the present study is the development of such a design, with focus on the assessment of the temporal aspect of episodic-like memories. In a series of three experiments we investigated whether the recall of temporal information from episodic memory is possible using a computerized recognition memory task. Instructions were replaced by an associative learning paradigm, which guided participants through the task.

The main questions arising: 1. If there is no automatic encoding, but rather a reconstruction of temporal information in episodic memory, as proposed by the reconstruction theory; can humans reconstruct the temporal context of an event, relying on the temporal order of subsequent events only without use of conventional time pattern? 2. Can the retrieval of temporal information be measured, when instructions are replaced by reinforcement resulting from button presses? If so; is the retrieval process based on real episodic recollection or is it a product of implicit feedback learning associations.

2. General methods

Participants

All participants reported having a normal or corrected vision and audition. Participants were recruited by announcements, signed an informed consent and a non-disclosure agreement. They were rewarded by money or received course credits.

Apparatus & Stimuli

The present study was conducted using a 17'' laptop (Toshiba; Japan), a headphone (Philips,Germany) and a USB mouse (Logitech, Switzerland) in the psychology data laboratory. The experimental software was implemented in python using Psychopy (Peirce, 2007) and the data analyzed using SPSS 20. The target stimulus consisted of 3 pictures (ladybird, port of Pisa, canola field) with a resolution of 600 x 800 Pixels. Pictures were presented sequentially centered on the screen (Experiment1 and 3) or simultaneously (Experiment 2) horizontally displayed next to each other. At observation distance of 50 cm, the pictures in the encoding phase had a length-to-width ratio of 15:20 and a size of 16.7 x 21.8° when presented sequentially and a length-to-width ratio of 33:7 and a size of 33.4 x 7.9° when presented simultaneously. Participants could respond to the stimuli by pressing one of four blue buttons, each with a length-to-width ratio of 3.5:2 and a size of 4 x 2.3°, which were displaced horizontally next to each other on the bottom of the screen. Auditory stimuli used for the reinforcement consisted of a car horn, a buzzer tone (negative reinforcement) and a cashier sound (positive reinforcement), visual stimuli consisted of a smiley (d =14.5 cm, 16.2°, positive reinforcement) and a black screen (full screen, negative reinforcement). Visual and acoustic reinforcement were presented immediately after response for a total time of 2 seconds.

Procedure

In each experiment participants passed respectively three consecutive Test days, spaced 24 hours apart. Consistent retention intervals between the three testing days make control for temporal confounding possible, such that participants can rely on temporal order only (today, yesterday, two days ago) as retrieval cue, emphasizing the role of the Test days.

Each daily session consisted of an encoding, recognition, a response and a reinforcement phase. Participants were seated in front of a computer screen and told that they will have to figure out task requirements, without getting verbal instructions. Furthermore they were asked to sign a non-disclosure obligation.We replaced instructions by an associative learning paradigm in which feedback guides the identification of task requirements. The experimenter started the task and immediately a fixation cross appeared and after an inter stimulus interval of 1 s the encoding phases started and a set of three pictures, randomly varying in order, was presented sequentially or simultaneously. The order of the pictures was chosen randomly out of six possible ones. After that the delay phase (30 s) was initiated in which the screen appeared grey. Responses to the grey screen were not possible.

In the subsequent recognition phase consisting of 10 blocks, each of 6 trials, a random order out of the set was presented sequentially or simultaneously. The picture order of the first encoding phase served as `today´s´ target sequence, while the other 5 sequences were `not encoded`. In the encoding phase of the next day another order was presented; this order served as `today´s´ target sequence, the order of the previous encoding phase assumed the role of ´yesterday's´ target sequence while the remaining 4 orders were `not encoded` and reduced by one on Test day3. This one served as `today´s´ target sequence, the order of the second Test day as ´yesterday's´ target sequence, the order of the first Test day as ´two-days-ago´ target sequence. The recognition of the picture order, of the recent and preceding encoding phases, served as a cue, to recall the associated temporal context (today, yesterday, two days ago), in the subsequent response phase. Participants could respond by pressing one of the displayed response buttons. The task could be solved, by applying a temporal order rule. The target picture orders were supposed to be matched to the day they were presented, by means of serving the displayed buttons. Three of these buttons functioned as time tags for ´today´, ´yesterday´ and ´two days ago´. The fourth was to be matched to the orders not ´encoded`. Participants received visual and acoustic reinforcement, a smiley, cashier sound, a 5 cent coin for correct responses and a black screen and an aversive car horn tone for incorrect responses. Not responding was associated with a buzzer.

To examine whether retrieval was based on recollection or other memory systems, after each daily session participants received an open questionnaire and were asked to write their hypothesis about task requirements. This general design was employed in three experiments. Details of the procedures are given in the method session of each experiment.

2.1 Experiment 1

In experiment 1 the computerized episodic-like memory task is tested. The recall of temporal order information can be inferred from behavioral measures, such as accuracy and response time. Temporal order information was presented during the encoding phase. The spatial configuration of this temporal information served as an additional retrieval cue in the recognition phase. If the temporal context of each picture sequence is recalled, participants should match the picture sequences properly to the displayed buttons, by means of applying the temporal order rule. Success in the assessment of temporal order information should be reflected in high accuracy, overall and on the single response buttons, short response latencies, generally and specifically in response to correct answers. If the assessment of temporal information does origins explicit from episodic memory, participants should be able to verbalize the temporal order rule behind serving the buttons in the questionnaire. If the source of this information is a superior memory system, participants should implicitly show high accuracy in the behavioral data, but not verbalize the temporal order rule in the questionnaire. If the assessment of temporal information fails, participants should show low accuracy in the behavioral data and in the questionnaire be unable to identify the temporal order rule that governs the role of the buttons.

2.1.1 Methods

Participants

33 psychology undergraduates (25 females, 93% right handed), from the Heinrich-Heine University of Duesseldorf, ranging in age between 17 and 63 years (*M* = 25.7, *SD* = 8.6), took part in the present study.

Procedure:

Participants were seated in front of a computer screen situated at eye level. In the encoding phase (see Fig. 1A) they saw three pictures in a randomized sequential order centered on the screen, each for 5 seconds, with an inter stimulus interval of 1 second. Immediately after presenting the last picture, the delay phase was started, and the computer screen remained grey for 30 seconds.

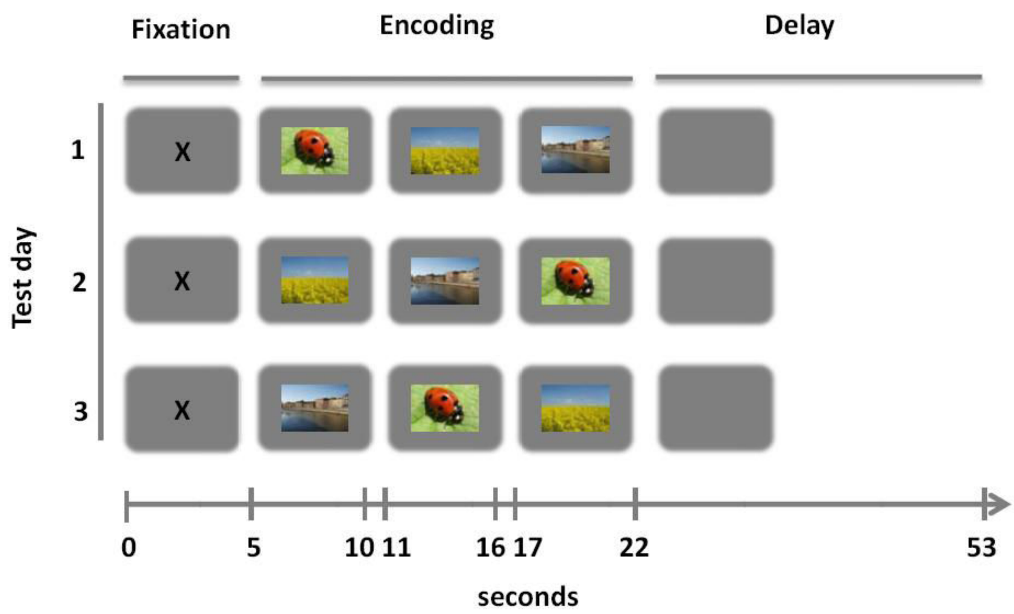


Figure 1A Illustration of the encoding phase in experiment1.

The recognition phase consisted of 60 trials with a variable inter trial interval ranging between 500 ms and 1500 ms. A recognition trial (see Fig. 1B) was initiated, by the randomized and simultaneous presentation, of a sequence of three horizontally displayed pictures, on the upper part of the screen. After a presentation time of 2 seconds the picture sequence disappeared. With the presentation of the 4 blue response buttons in the lower part of the screen, the response phase was initiated for a total time of 15 seconds.

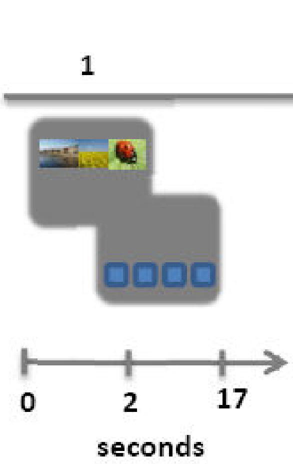


Fig. 1B Illustration of a recognition trial.

The temporal order rule grew larger with the Test days. On Test day1, participants were required to match the initially encoded picture sequence to the first most left, and the five other picture sequences, not seen in the encoding phase, to the fourth most right button. 24 hours later the second test was conducted. Additionally to matching the recent seen picture sequence to the first button, and the not seen picture sequences to the fourth, the picture sequence of the encoding phase of the first Test day, was to be matched to the second button. After a retention interval of 24 hours the third test started. The task of the participants was the same, except that the picture sequence seen in the encoding phase of Test day2 was to be matched to the third button.

Performance was reinforced using visual and auditory stimuli (see Fig. 1C). Correct answers elicited a yellow smiley and a cash box sound. Incorrect answers provoked an aversive hoot. If participants faded to respond for 10s, a buzzer tone sounds for 5 seconds. Not responding at all was treated as incorrect.

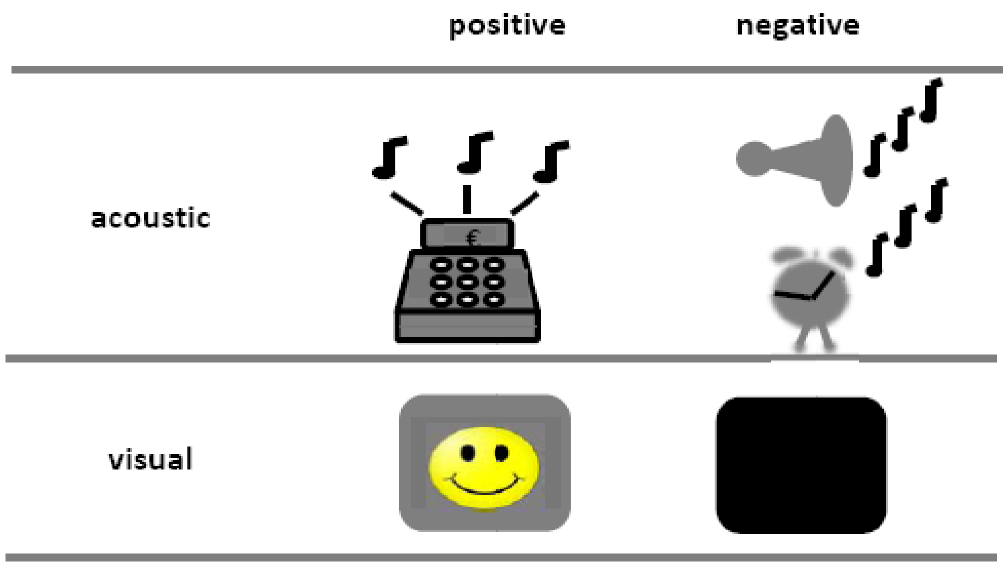


Fig. 1C Illustration of feedback to correct and incorrect responses.

Data analysis

Accuracy (percentage of correct responses) was analysed with a repeated-measures analysis of variance (ANOVA), solely with the factor Test day (3) and additionally, with the factor Block (10). Relative accuracy was analysed with a repeated measure ANOVA with the factor Button, with 2 levels on Test day1, 3 levels on Test day2 and 4 levels on Test day3. Reaction time (time from button onset to response) was analyzed with a repeated measure ANOVA, using the factor Test day (1, 2, 3) and a second factor Response type (correct, incorrect). Trials with responses longer than 15 seconds were defined as incorrect. We used an alpha level of .05 for all statistical tests. Post hoc analyses were conducted using two-tailed Bonferroni corrected T-Tests or Bonferroni corrected pairwise comparisons.

For descriptive post hoc analyses we assigned participants into three groups, according to their answer in the explicit questionnaire. Participants who formulated the temporal order rule formed the episodic recollection group (EpRec-Group). Those who verbalized a semantic rule, that matched picture sequences to buttons, without identifying the underlying temporal order rule, formed the semantic recognition group (SeRec-Group). Participants who did not report any rule were assigned to the nonRecognition group (nRec). 3 participants (outliers) were excluded from analysis because they did not respond in over 50% of the trials.

2.1.2 Results

Analysis on verbal disclosure

On Test day1, no participant identified the temporal order rule. On day 2 however, 7% (n=2) of the participants identified the temporal order rule, and on Test day3 their proportion grew to 10 % (n=3). Furthermore, 70% (n=21) of the participants on Test day1, 67% (n=20) on Test day2 and 63 % (n=19) on Test day3, identified task requirements by means of the semantic rule. 30% (n=9) of the participants on Test day1, 27% (n= 8) on Test day2 and 3 did not apply any rule. Thedetailed responses of all participants are found in the appendix.

Analysis on accuracy across the three days

Mean accuracy rates are shown in figure 2 for each of the three testing days. Trend of the accuracy rates, across the ten blocks of trials, are plotted for all participants, across the single days in figure 3. The ANOVA showed significant effects of the Test day (F (2, 58) = 3.46, p = .038, η^2 = .106), Block (F (9, 261) = 22.69, p = .000, η^2 = .439) and a significant interaction between Test day and Block (F (9.7, 281.9) = 11.31, p = .000, η^2 = .281). Overall accuracy was significantly higher on Test day2 (M = 59%, SE = 3%) than on Test day3 (M = 52%, SE = 3%), (t *(29)* = 2.65, p < .016). No significant differences could be found between Test day1 (M = 51%, SE = 3%) and 3, and Test day1 and 2 (p > .016).

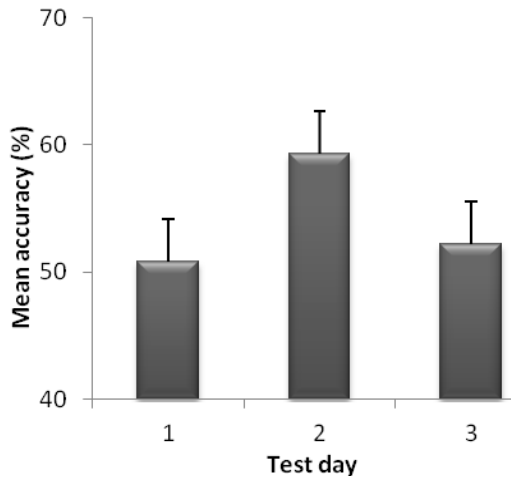


Fig. 2 Mean accuracy among the single Test days. Participants were most accurate on Test day2. Error bars show standard error.

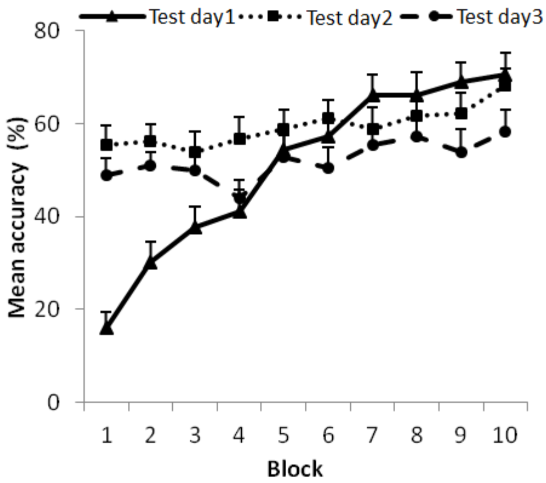


Fig. 3 Mean Accuracy across the 10 blocks of the single Test days. Slope of learning curve was steeper on Test day1 than on 2 or 3. Error bars show standard error.

On Test day1 accuracy rates ascended significantly across blocks, (t (29) = -10.92, p < .016), as well as on Test day2, (t (29) = -8.10, p < .016), but not on Test day3 (p > .016). Accuracy rates in block1 differed significantly between Test day1 and Test day2, (t (29) = -7.86, p < .016), Test day1 and Test day3, (t (29) = -6.79, p < *.016),* but not between Test day2 and Test day3, (t (29) = 1.48, p = .149). Accuracy rates in block10 varied significantly between Test day2 and Test day3, (t (29) = 2.70, p < .016), but not between Test day1 and Test day3 and Test day1 and Test day2 (p > .016). While low accuracy on Test day1 might be a product of uncertainty considering task requirements, also observable in inferior performance on block1 of Test day1, drop in accuracy from Test day2 to Test day3 could be ascribed to increasing difficulty caused by the high number of to be tested sequence-buttons associations, also observable in the nearly flat learning curve of Test day3 and in the declination in performance in block10 of Test day3.

Analysis on accuracy by groups

Descriptive analysis on accuracy across the groups, is plotted in figure 4A and revealed that, the EpRec-Group was more accurate on Test day2 (n=2, *M* = 89%, *SE* = 7.5%) than Test day3 (n=3, *M* = 78%, *SE* = 16%). Trends of accuracy (see Fig. 4B) were ascending on Test day2 and nearly flat on Test day3. The SeRec-Group was more accurate on Test day2 (n=20, *M* = 60%, *SE* = 4%) than on Test day1 (n=21, *M* = 55%, *SE*= 4%) and Test day3 (n=19, *M* = 49%, *SE* = 4%) as well. Trends of accuracy (see Fig.4C) were ascending on Test day1 and 2. A flatter slope was observed on Test day3.The nRec-Group, revealed low accuracy on Test day1 (n=9, *M* = 41%, *SE* = 7%), Testday2 (n=8, *M* = 51%, *SE* = 3%) and Test day3 (n=8, *M* = 50%, *SE* = 3%). Trends of accuracy (see Fig. 4D) were ascending on Test day1 and nearly flat on Test day2 and 3. As obvious in fig. 4A the EpRec-Group´s performance exceeds that of both other groups.

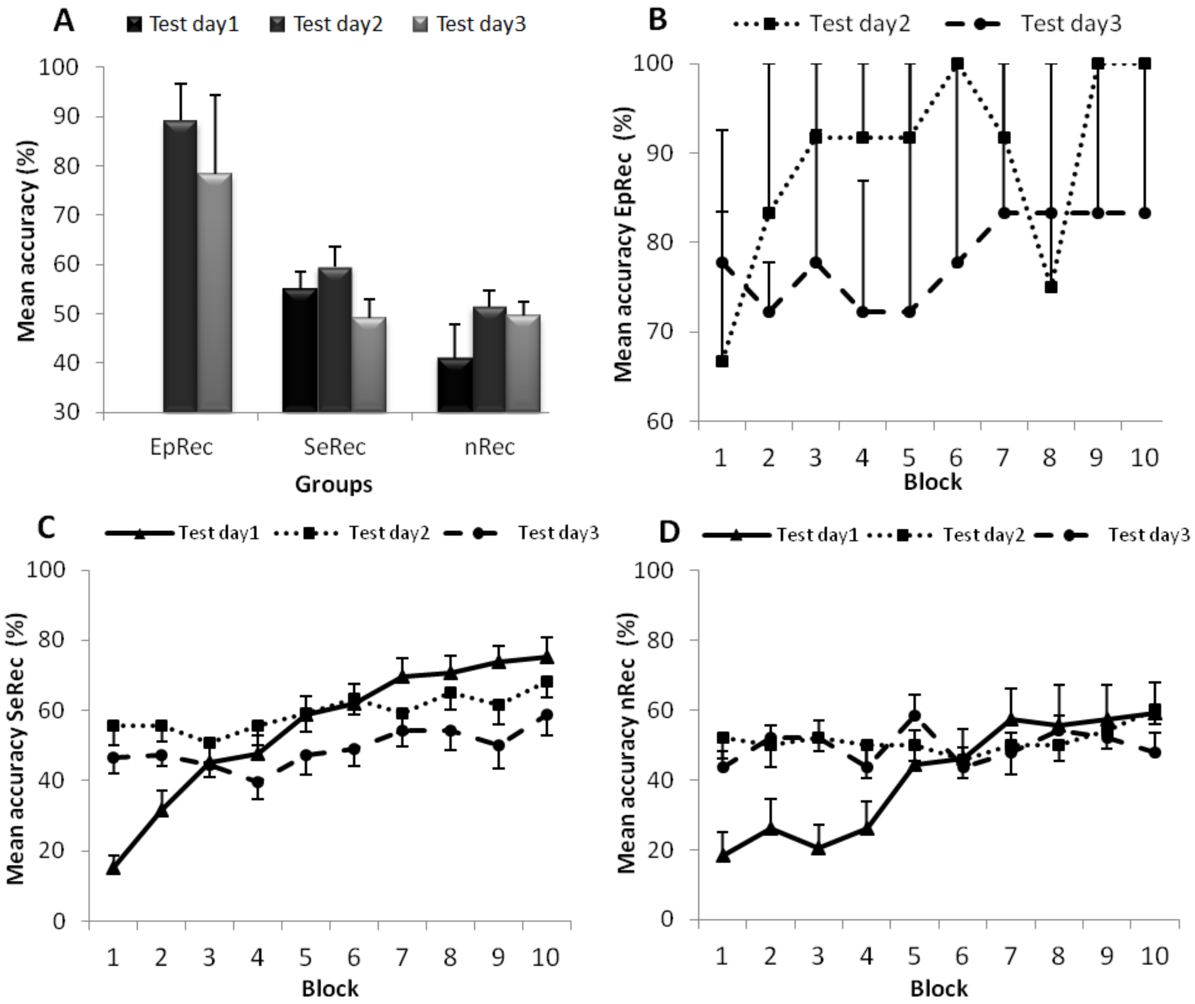


Fig. 4 Mean accuracy on the Test days across the groups (Fig. 4A). Notice that the EpRec-Group was most accurate across both Test days, followed by the SeRec-Group. Mean Accuracy across the 10 blocks on the single Test days plotted separately for the participant who verbalized the temporal order rule (4B, EpRec), those who formulated a semantic rule (4C, SeRec) and those who did not report any rule (4D, nRec). Slope of the learning curve was steeper on Test day1, while slope on Test day2 and 3 was comparable low. Error bars show the standard error of the mean (SE).

Analysis on behavioral button responses across the days

Relative accuracy on the single buttons of the testing days is shown in figure 5. On Test day1, relative accuracy varied across the buttons, (F (1, 29) = 8.88, p = .006, $\acute{\eta}^2$ = .23), where relative accuracy on button4 was higher than on button1. On Test day2, a main effect of the factor Buttons (F (2, 58) = 45.46, p = .000, $\acute{\eta}^2$ = .61) was found.

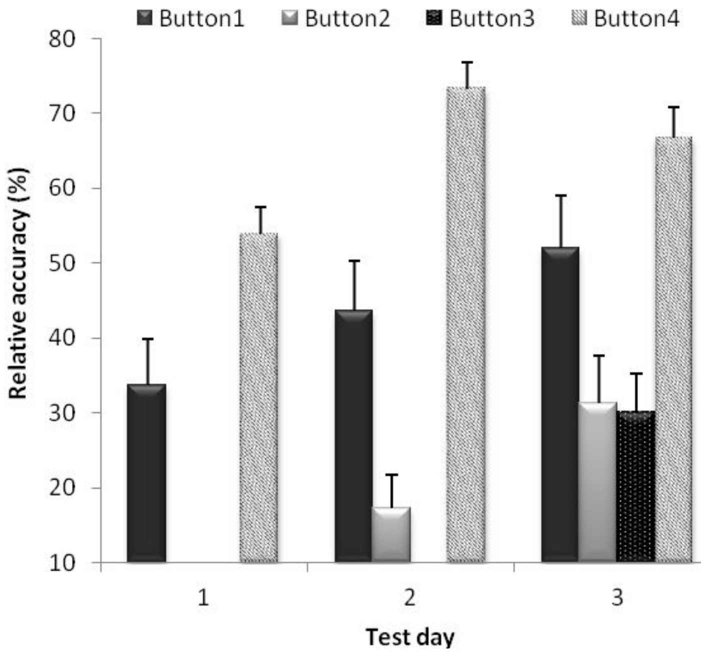
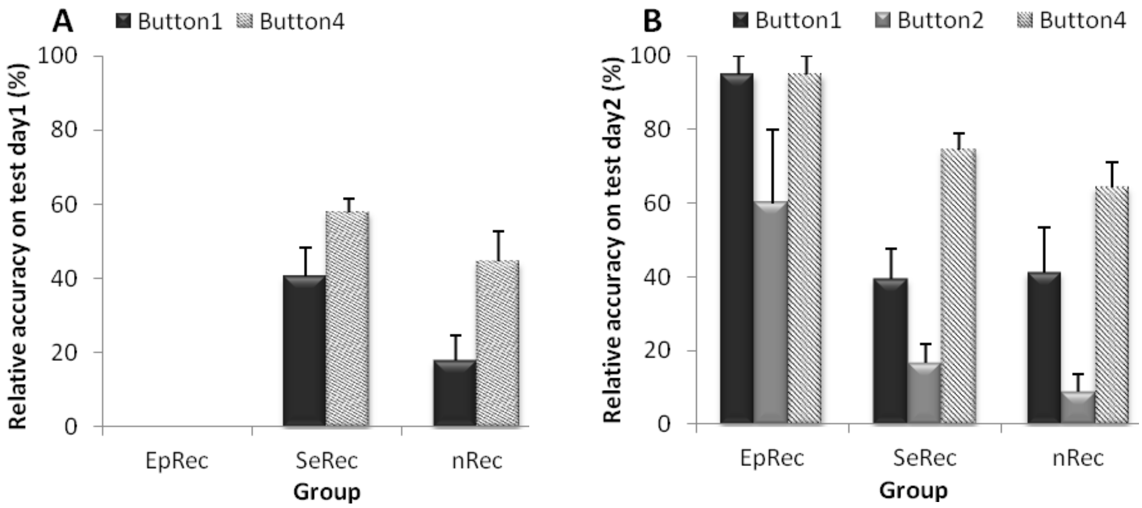


Fig. 5 Relative accuracy among all participants on the single buttons of the three Test days. Participants were most accurate on button 4 followed by button1. Error bars show the standard error of the mean (SE).

Pairwise comparisons revealed that, accuracy on button1 was higher than on button2 (*MD* = 26.33, *p* =.000) and inferior to accuracy on button4 (*MD* = -29.58, *p* = .000). Accuracy was higher on button4 than on 2 (*MD* = 55.92, *p* = .000). On Test day3, relative accuracy data revealed a main effect of the factor Buttons (F (3, 87) = 11.35, p = .000 η^2 = .28). Relative accuracy on button4 was higher than on button2 (*MD* = 35.33, *p* = .000) and button3 (*MD* = 36.67, *p* = .000). Relative accuracy was highest on button4 followed by button1, pointing to the possible identification of button1 as a temporal marker for `today`.

Analysis on button responses by groups

Relative accuracy, on the buttons of the single Test days across the groups, is shown in figure 6A for the EpRec-Group, in figure 6B for the SeRec-Group and in figure 6C for the nRec-Group. On Test day2 the the EpRec-Group (n=2) was equally accurate on button1 and button4. The same pattern could be observed on Test day3 (n=3). Accuracy on button2 was lower than accuracy on button4 on Test day2 and 3. Button3 yielded the lowest accuracy. On Test day1 the SeRec-Group (n=21) was more accurate on button4 than on button1. The same pattern could be observed on Test day2 (n=20) and Test day3 (n=19). Accuracy on button2 was lower than accuracy on button4 on Test day2 and Test day3. On Test day3 accuracy on button3 was lower than accuracy on button4. On Test day1 the nRec-Group was more accurate on button4 than on button1 (n=9). The same pattern could be observed on Test day2 and 3 (n=8). Accuracy on button2 was lower than accuracy on button4 on Test day2 and 3. On Test day3 accuracy on button3 was lower than accuracy on button4. The EpRec-Group performed better on all buttons. Noticeable is that the distribution pattern of relative accuracy among the buttons is highly similar across the groups, with higher performance on button4 than button1 and nearly equal performance on button 2 and 3 on Test day3.



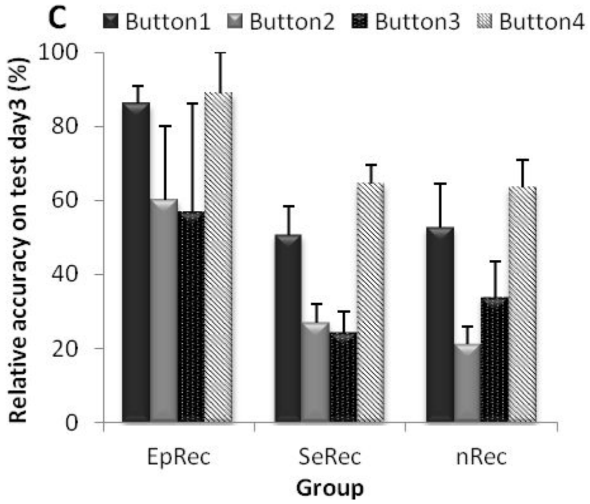


Fig. 6 Relative accuracy on the buttons of the single Test days across the groups on Test day1 (Fig. 6A), Test day2 (Fig. 6B) and Test day3 (Fig. 6C). Notice that button4 was most accurately used followed by button1 in all three groups on all three Test days. Error bars show the standard error of the mean (SE).

Analysis on reaction time

Mean reaction time of all participants is shown in figure 7A. Reaction time on Test day1 (M = 3482.61 ms, SE = 544.0 ms) was higher than on Test day2 (M = 2356.97 ms, SE = 214.9 ms) and Test day3 (M = 2388.46 ms, SE = 212.77 ms). The ANOVA, revealed a significant main effect of the Test day, (F (1.03, 29.88) = 5.84, p = .021, η^2 = .17). Pair wise comparisons revealed higher reaction times on Test day1, compared to Test day2 (MD = 1125.64, p < .043) and Test day3 (MD = 1094.15, p < .030), but no significant difference between Test day2 and 3 (p > .05). Declination in reaction time from Test day1 to Test day2 and 3 resulted from higher confidence regarding task requirements.

Figure 7B shows mean response latencies, for correct and incorrect answers, on each Test day. Participants responded faster on correct answers on all Test days. The ANOVA revealed a significant main effect of the Test day (F (1.15, 32.2) = 12.19, p = .001, $\acute{\eta}^2$ = .303), Response type (F (1, 28) = 28.78, p = .000, $\acute{\eta}^2$ = .507) and a significant interaction between the two factors (F (1.17, 18.12) = 18.12, p = .000, $\acute{\eta}^2$ = .393). A post-hoc analysis showed that reaction times were significant faster on correct than incorrect answers on Test days 1, (t (29) = -4.97, $p < .016$) and 2, (t (29) = -2.67, $p < .016$), but not 3, (t (29) = -1.21, p = .796). A significant reduction in reaction time, for incorrect answers, on Test day1, could be observed, compared to Test day2, (t (29) = 3.93, $p < .016$) and Test day3, (t (29) = 3.79, $p < .016$), but not between Test days 2 and 3, (t (29) = 0.910, p = .370). No differences were found, comparing the reaction time to correct answers between Test day1 and 2, (t (29) = 0.26, p =.315), Test day1 and 3, (t (29) = -1.02, p = .315) and Test day2 and 3, (t (29) = -1.68, p = .104). Faster responses on correct answers resulted from accelerated information processing and enhanced recall of the associated temporal context.

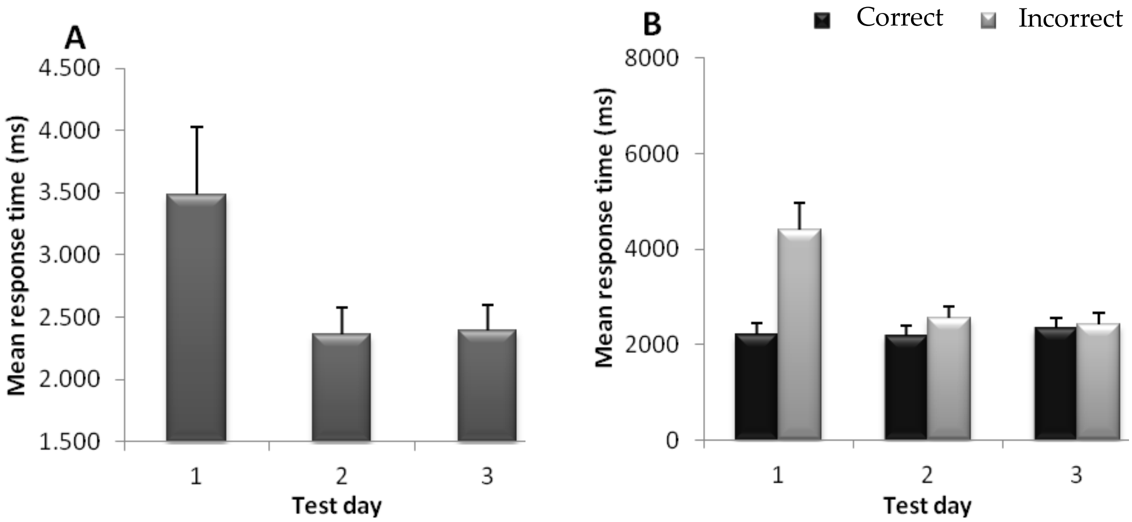


Fig. 7 Mean response time on the single Test days (Fig. 7A) and on correct and incorrect answers on the single Test days (Fig. 7B) of all participants. Participants were slower in responding on Test day1 and equal fast on Test day2 and 3. Higher reaction latencies on the first Test day resulted from slower reactions to incorrect answers. Error bars show the standard error of the mean (SE).

Analysis on reaction times by group

A descriptive analysis on reaction times between the groups (see Fig. 8A) revealed that, on Test day1 the SeRec-Group (n=21) was faster than the nRec-Group (n=9). On Test day2, the EpRec-Group (n=2) was faster than the SeRec-Group (n=20) and the nRec-Group (n=8). On Test day3, the behavioural pattern of the EpRec-Group (*n=3)*, the SeRec-Group (n=19) and the nRec-Group (n=8) was consistent with that on Test day2.

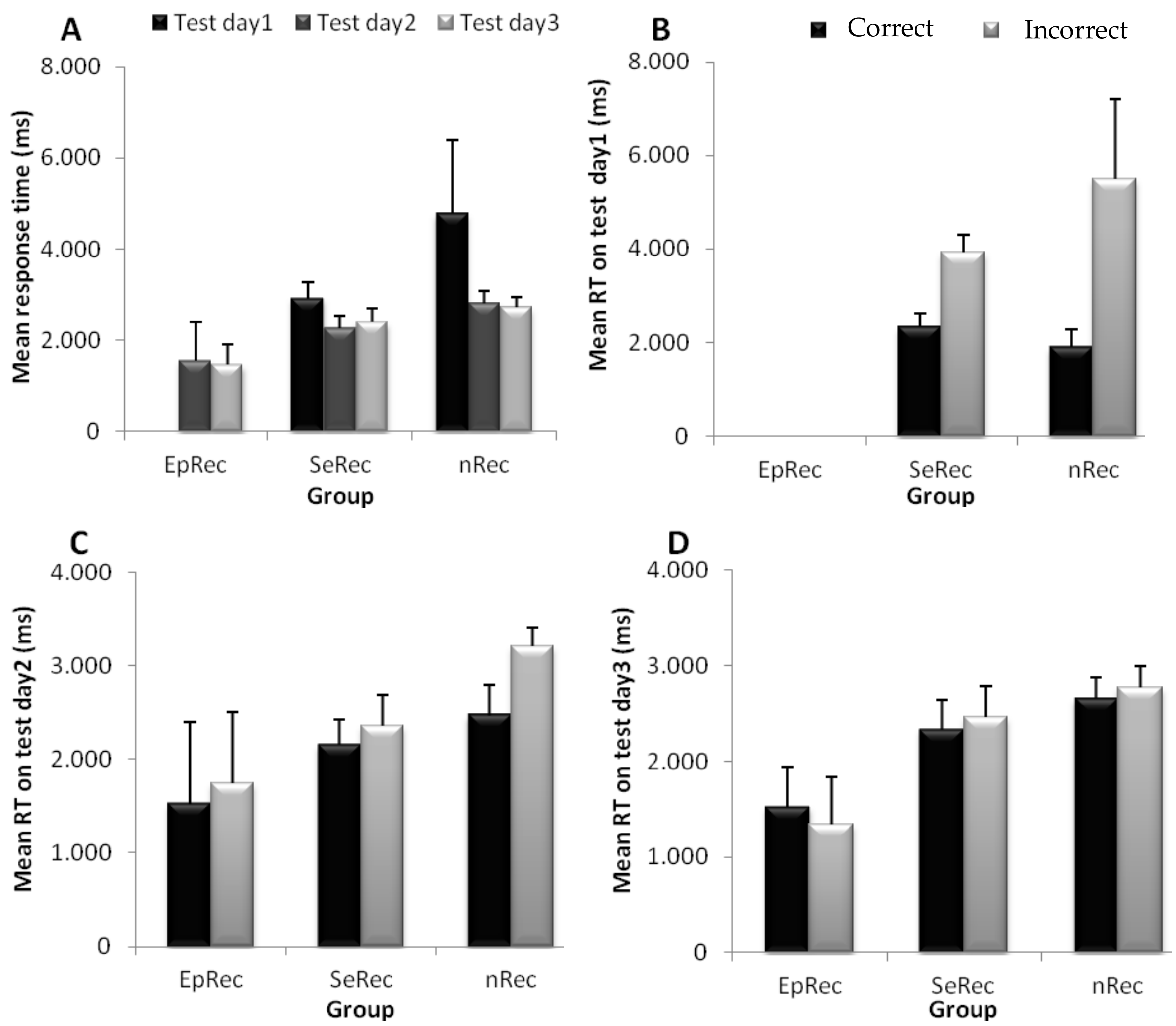


Fig. 8 Mean response time (RT) on the single Test days across the groups (Fig. 8A) and on correct and incorrect answers on Test day1 (Fig. 8B), Test day2 (Fig. 8C) and Test day3 (Fig. 8D). Participants of the EpRec group responded faster on all Test days. Participants of all group responded faster to correct and slower to incorrect answers. Error bars show the standard error of the mean (SE).

A descriptive analysis on the reaction times, for correct and incorrect answers, between the groups, on Test day1 (see Fig. 8B), Test day2 (see Fig. 8C) and Test day3 (see Fig. 8D) revealed that, on Test day1 the SeRec- (n=21) and the nRec-Group (n=9) responded faster to correct than incorrect answers. On Test day2 the same trend could be observed for the EpRec- (n=2), the SeRec- (n=20) and the nRec-Group (n=8). On Test day3 response latency to correct and incorrect responses were similar in the EpRec- (n=3), the SeRec- (n=19) and the nRec-Group (n=8), indicating that out task cannot be solved when applying a semantic rule. Faster responses on correct answers resulted from accelerated information processing and enhanced recall of the associated temporal context.

2.1.3 Discussion

It is reasonable to assume that the strength of memory trace determined which picture sequence was recognized. The decay theory postulates that memory traces fade with elapsed time (J. Brown, 1958; Thorndike, 1913). Due to the short retention interval, the memory trace of the recently seen picture sequence was stronger than that of the previous days and was more easily recognized and matched to the correct button by means of testing picture sequence-buttons-associations. As the retention interval was extended to 24 hours the memory trace decayed and participants no longer recognized yesterday’s critical picture sequence or the one seen two days before. As a result, they were not able to recall the temporal context associated with this sequence.

Even though decay of memory trace explains performance in this task it is unlikely that it was the primary reason for recognition and recall failure. Instead, methodological shortcomings might also have contributed to it. In the recognition phase, the sequential order of the critical pictures sequence was turned into a spatial one. We assumed that the presentation of an additional spatial cue to the recognition phase would enhance recognition of the critical picture sequence and recall of the temporal context associated to that sequence, leading to more correct responses on all three Test days. However the need to infer the spatial information from the sequential one may also impair recognition, since additional cognitive effort was required. Furthermore, it does seem that task difficulty might have been incremented by the simultaneous presentation of the four response buttons on all testing days. This resulted in 24 button-sequence-associations, for participants to explore.

Behavioral data are supported by the questionnaire data. On Test day1, only short-term recognition of the sequence was required and no temporal order rule was to be abstracted. The task could be solved by familiarity using new old judgments, once button1 was identified as correct for the recent encoded sequence and button4 for the others. The majority of the participants (66.5% on Test day2 and 63% on Test day3) reported that they used a semantic rule to solve the task, while the minority could not abstract any rule. That is why participants of the SeRec-Group performed better than those of the nRec-Group, showing steeper learning curves, lower response latencies and higher accuracy rates. Test day2 is the one in which participants could acquire knowledge about the temporal order rule, which encompassed recall of the temporal context of the recently viewed and the picture sequence seen on the previous day. Only 2 participants could verbally reproduce the temporal order rule, while the 23 reported using a semantic rule. The EpRec-Group performed better than the SeRec-Group whiles the SeRec-Group performed better than the nRec-Group. The trend of accuracy illustrates different learning performance with steeper learning curves for the EpRec- and SeRec-Group and constant performance in the nRec-Group. Performance on button1, 2 and 4 of the SeRec-Group was slightly higher than that of the nRec-Group implying that the nRec-Group might have acquired and applied more implicit knowledge, which was explicitly not accessible. On Test day3, the knowledge acquired on of Test days2 and

1 was to be transferred and extended. As the SeRec- and nRec-Group failed to abstract the temporal order rule, required to be applied on Test day3, their performance was inferior to that of the EpRec-Group.

Descriptive group differences revealed that, high accuracy rates (65% and 75%) on the task can be achieved when applying a semantic, rather than a temporal order rule, on Test day1 and 2, but not on Test day3. This underlines the importance of the third Test day in giving disclosure about the acquisition of temporal order information. The participants were unable to recognize the critical picture sequences of the previous days and, as a consequence, also unable to recall the associated temporal context. Behavioral and verbal data suggest that the participants acquired and applied only parts of the temporal order rule in response to short term recognition. The amount of information gain seems to be a function of task difficulty. Therefore, in experiment 2 the effect of reduction of task difficulty on performance was explored.

2.2 Experiment 2

Discussing experiment 1 we argued that switching from the sequential order of the pictures in the encoding phase to a spatial one in the recognition phase, could have increased cognitive load. We modified our task and presented the pictures in the encoding phase simultaneously. Furthermore, we successively raised the number of on the screen presented buttons, from 2 on Test day1, to 3 on Test day2, and 4 on Test day3. We hypothesized that using spatial order in the encoding phase, could enhance recognition of the critical picture configuration. Additionally, we expected that the successive presentation of the buttons could emphasize temporal contingencies to the picture sequences, leading to higher accuracy on all three Test days, and possibly to the identification of the temporal order rule in the verbal disclosure. We framed the same hypotheses as in experiment 1.

2.2.1 Methods

Participants

43 psychology undergraduates (25 females, 90% right handed), from the Heinrich-Heine University of Duesseldorf, ranging in age between 19 and 36 years (*M* = 23.8, *SD* = 3.57), took part in the present study.

Procedure

The general procedure in experiment 2 was as in experiment 1. Different were (1) the spatial component in the encoding phase (see Fig. 9A), (2) the successive presentation of the response buttons in the recognition phase (see Fig. 9B) and (3) additionally monetary incentives as feedback (see Fig. 9C). In the encoding phase a randomized order of three pictures was presented for 15 seconds, centred horizontally, in the upper part of the screen.

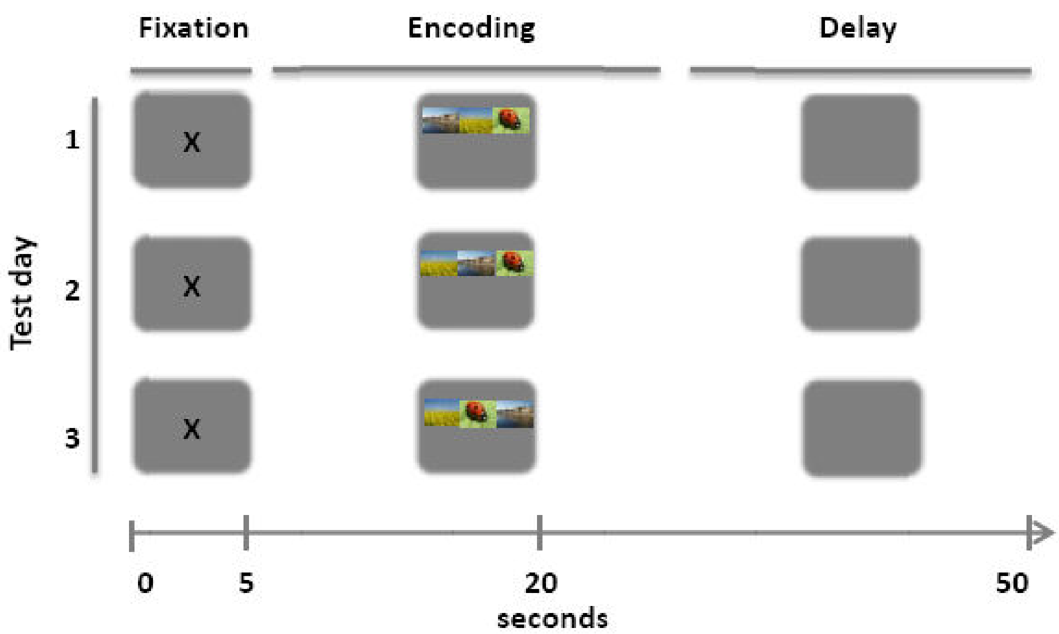


Fig.9A Illustration of the procedure of the encoding phase in experiment 2.

Following a delay of 30 seconds, participants passed through 60 recognition trials, with an inter trial interval between 500 ms and 1500 ms, in which they repeatedly saw the same pictures in varying order, each picture sequence for 15 seconds. In the subsequent response phase, participants were presented two (Test day1, one left, one right), three (Test day2, one left, one right and an additional button next to the left), or four (Test day3, left, right, 2 intermediate) response buttons for a total time of 15 seconds.

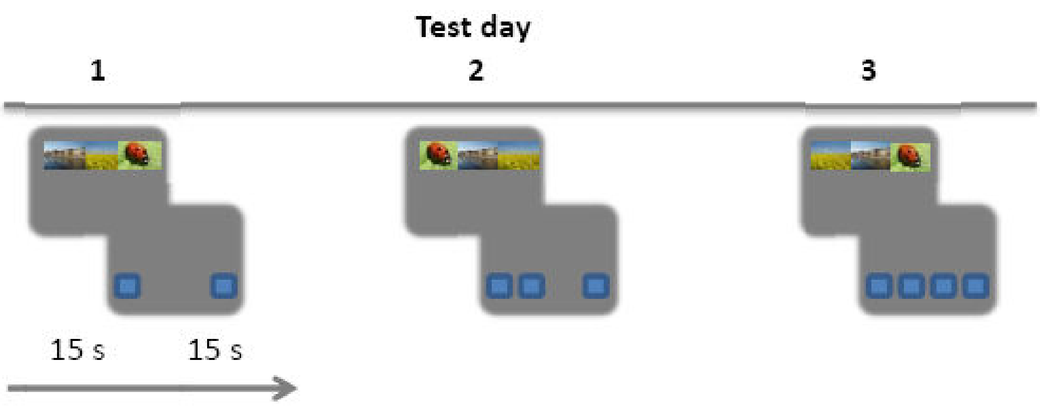


Fig. 9B Illustration of the procedure of the recognition phase in experiment 2.

The temporal order rule that governed the assignment of picture sequences to the buttons was the same as in Exp.1. Different from the first experiment, a 5 cent coin was dropped into a bowl upon each correct answer.

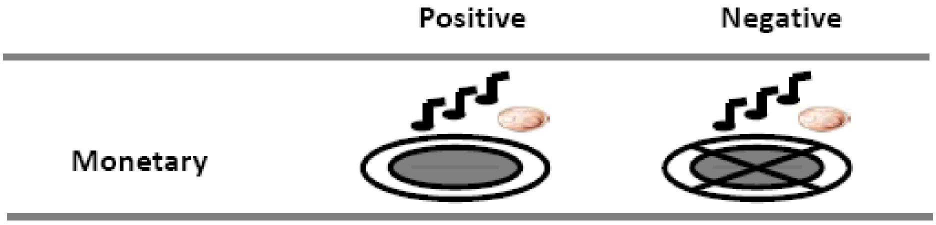


Fig. 9C Illustration of the presentation of the monetary incentives.

Data analysis

See Experiment 1

2.2.2 Results

Analysis on verbal disclosure

On Test day1 the temporal order rule was identified by 5% (n=2) of the participants. On day 2 and 3 this proportion increased to 7.5% (n=3). 47.5% of the participants on Test day1 (n=19), 42.5% on Test day2 and 3 (n=12) identified task requirements by means of the semantic rule. Finally 47.5% of the participants on Test day1 (n=19), 50% (n=20) on Test day2 and 3 did not identify task requirements at all. The detailed responses of all participants are given in the appendix.

Analysis on accuracy

Mean accuracy rates are shown in figure 10 for each of the three testing days. Trend of the accuracy rates across the ten blocks of trials are plotted for all participants across the Test days in figure 11. The ANOVA showed significant effects of both, Blocks (F (5.4, 209.7) = 48.53, p = .000, η^2 = .554) and the Test day, (F (2, 78) =

8.31, p = .001, $\acute{\eta}^2$ = .176) and a significant interaction between the Blocks and Test day, (F (9.4, 367.1) = 8.31, p = .001, $\acute{\eta}^2$ = .090). Accuracy rates on Test day1 (M = 64%, SE = 3%) and 2 (M = 67%, SE = 3%) were both significantly higher than on Test day3 (M = 55%, SE = 4%), (t (39) = 2.92, p < .016) and (t (39) = 4.44, p < .016) respectively, but did not differ from one (t (39) = -0.803, p = .427). Declination in accuracy from Test day 1 and 2 to Test day 3 resulted from increasing task difficulty induced by the high number of to be explored sequence-button associations.

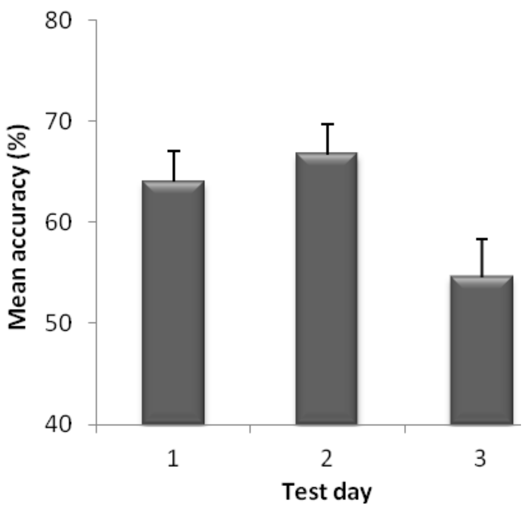


Fig. 10 Allover accuracy among the single Test days. Participants were most accurate on Test day1 and 2. Error bars show the standard error of the mean (SE).

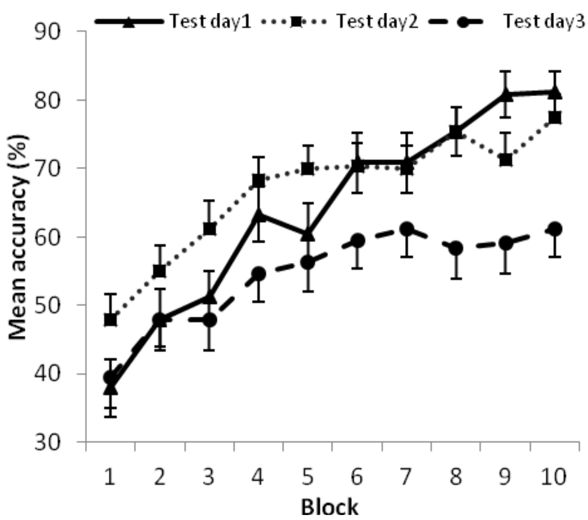


Fig. 11 Mean accuracy across the 10 blocks of the single Test days. Slope of learning curve was steepest on Test day1 followed by Test day2 and 3. Error bars show the standard error of the mean (SE).

On Test day1, accuracy rates ascended significantly from block1 to 10, (t (39) = -10.19, p = .000). On day2, accuracy rates also ascended beginning at a moderate accuracy and rose significantly in block10, (t (39) = -8.10, p = .000). On day3, the gain in accuracy was significant from block1 to block10, (t (39) = -6.21, p = .000). Accuracy rates in block1 did not differ significantly between Test days 1 and 2, (t (39) = -1.73, p = .092), 1 and 3, (t (39) = -.35, p = .726) and 2 and 3, (t (39) = 2.02, p = .051). Accuracy rates in block10 differed significantly between Test days 1 and 3, (t (39) = 4.15, p <

.016), 2 and 3, (t (39) = 4.57, $p < .016$) but not between 1 and 2, (t (39) = 1.22, $p = .229$). Low accuracy on block1 of Test day 1 reflects uncertainty, which decreased with the subsequent blocks. Increasing confidence with task requirements is found in the higher accuracy in block1 of Test day2. But with increasing task difficulty on Test day3 the higher accuracy of Test day1 declines in order to reach the level of Test day1.

Analysis on accuracy by the groups

Descriptive analysis of accuracy of the groups is plotted in figure 12A. It revealed that, on Test day1 the EpRec-Group (n=2) was more accurate (*M* = 83%, *SE* = 18%) than on Test days 2 (n=3, *M* = 76%, *SE* = 7%) or 3 (n=3, *M* = 77%, *SE* = 19%). Accuracy (see Fig. 12B) increases steeply on Test day1, shallowly on day2 and as good as not on day3. Accuracy of the SeRec-Group was high overall, and higher on day2 (n=17, *M* = 76%, *SE* = 4%) than on day1 (n=19, *M* = 67%, *SE* = 5%) and 3 (n=17, *M* = 64%, *SE* = 5%). Accuracy (see Fig. 12C) increased across the blocks on all days. The nRec-Group addresses moderate accuracy on Test day1 (n=19, *M* = 59%, *SE* = 4%), 2 (n=20, *M* = 57%, *SE* = 3%) and 3 (n=20, *M* = 43%, *SE* = 4%). Accuracy (see Fig. 12D) increased across the blocks on all days1, 2 and 3. Higher accuracy of the EpRec-Group on Test day1 points to knowledge about task requirements prior to participation. Higher performance of the SeRec-Goup when compared to the nRec-Group indicates that parts of the temporal order rule can be substituted by a semantic rule.

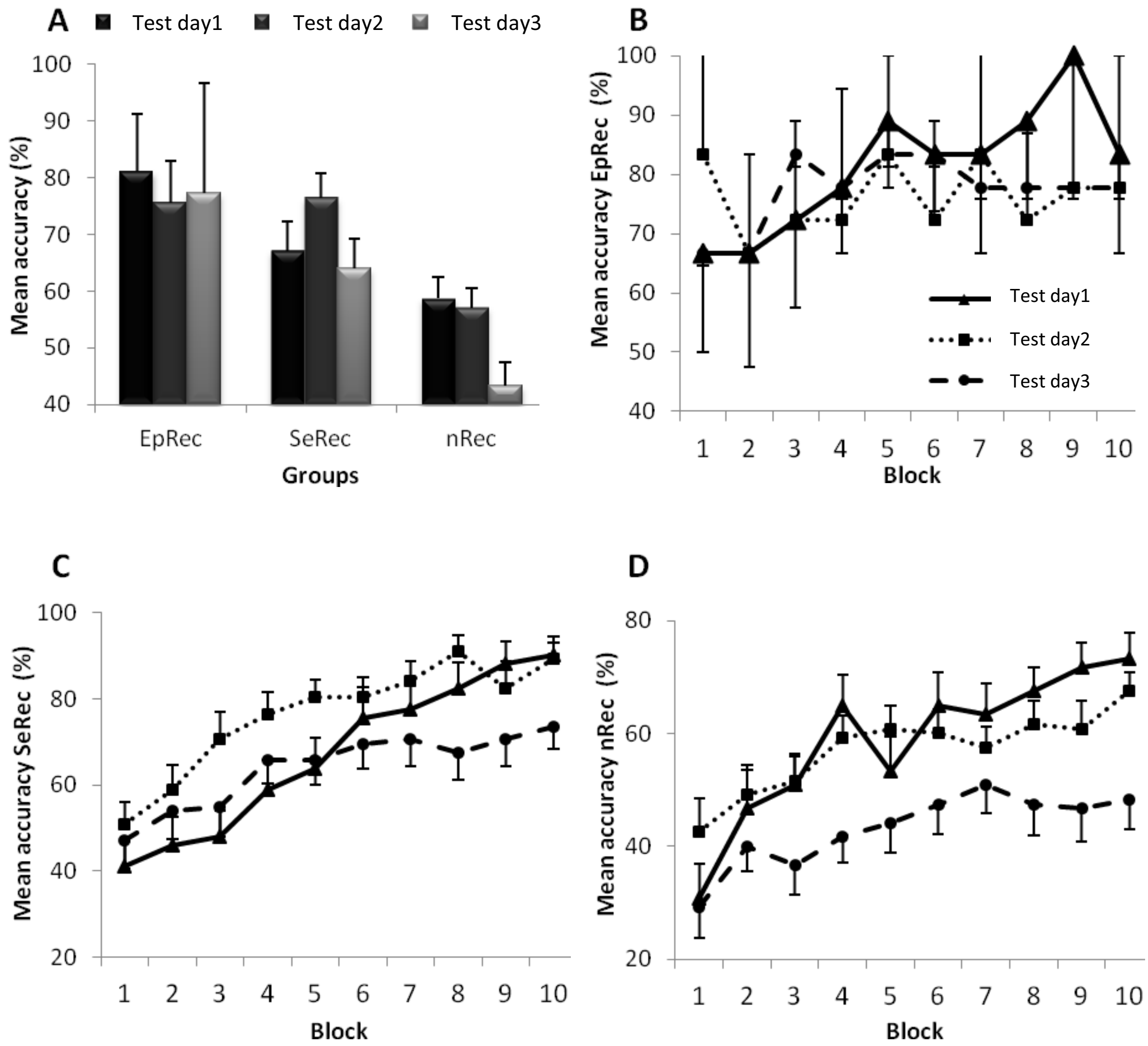


Fig. 12 Mean accuracy on the Test days across the groups (Fig. 12A). Notice that the EpRec-Group performed best on all three Test days, followed by the SeRec-Group. Mean accuracy across the 10 blocks on the single Test days are plotted separately for the participant who identified the temporal order rule (12B, EpRec), those who identified a semantic rule (12C, SeRec) and those who did not apply any rule (12D, nRec). Among all groups slope of the learning curve was comparable steep on Test day1 and 2, while slope on Test day3 was comparable low. Error bars show the standard error of the mean (SE).

Analysis on behavioral button responses

Relative accuracy on the single buttons of the testing days is shown in figure 13. On Test day1, relative accuracy varied across the buttons, (F (1, 39) = 335.33, p = .000, η^2 = .89), where relative accuracy on button4 was higher than on button 1. On

Test day2, a main effect of the factor Buttons, (F (1.12, 43.8) = 252.47, p = .000, η^2 =. 87), was found.

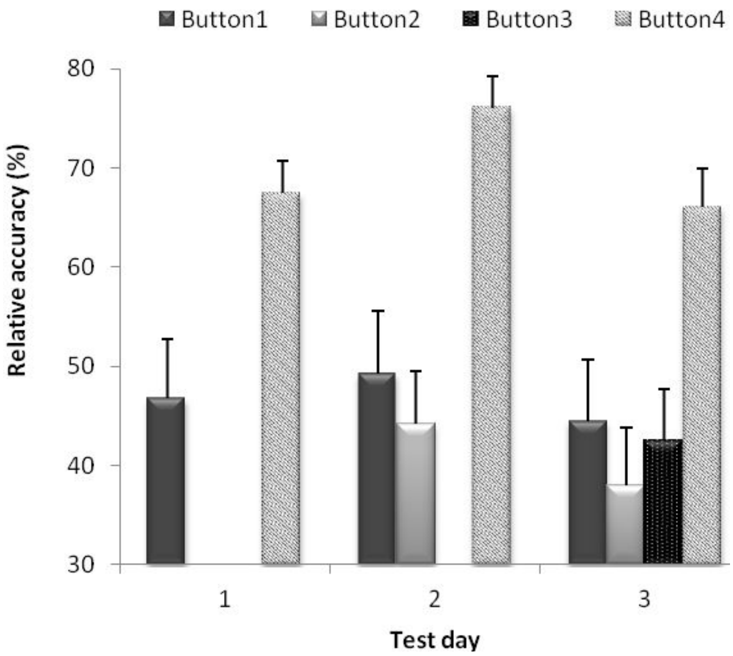
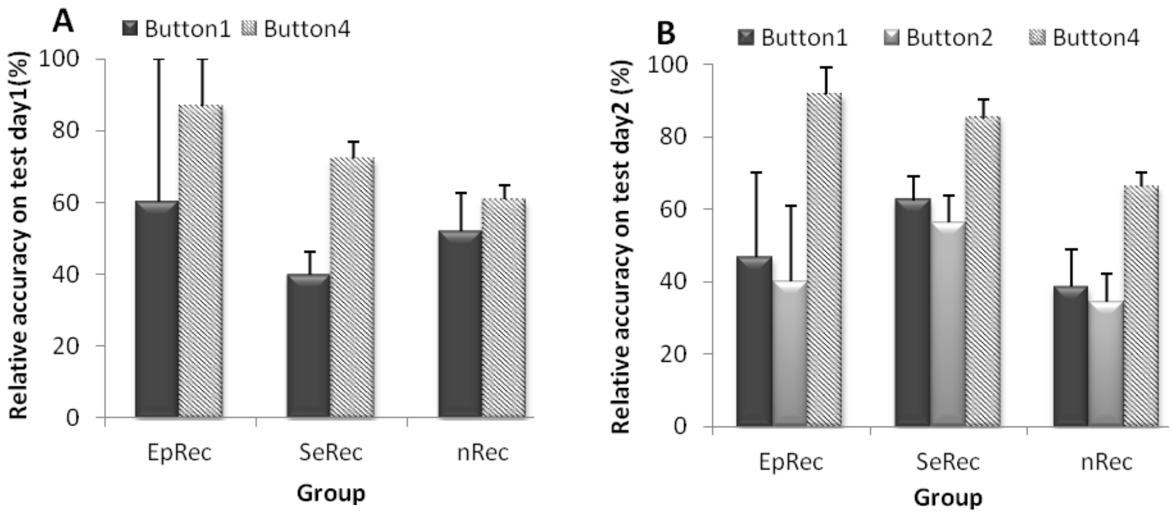


Fig. 13 Relative accuracy across all participants on the four individual buttons of the three Test days. Participants were most accurate on button4 followed by button1. Error bars show the standard error of the mean (SE).

Pairwise comparisons revealed that, accuracy on button4 was higher than on button1 (MD = 42.08, p = .000) and button2 (MD = 42.08, p = .000). On Test day3, relative accuracy data revealed a main effect of the factor buttons F (1.87, 73.00) = 139.25, p = .000 η^2 = .78. Relative accuracy on button4 was higher than on button1 (MD = 25.6, p = .000), button2 (MD = 26.00, p = .000), and button3 (MD = 25.9, p = .000). Higher accuracy on button1 and 4 over all three testing days indicates that participants might have been solving the task using old-new judgments.

Analysis on behavioral button responses by groups

Relative accuracy on the buttons of the single Test days for individual groups is shown in figure 14A for the EpRec-Group, in figure 14B for the SeRec-Group and in figure 14C for the nRec-Group. All groups performed on all days better on button 4 than on button1, and on button 2 of Test day 2 and 3 equal good as on button 1. Performance of the EpRec-Group was as expected best on all buttons, emphasizing the importance of identifying the temporal order rule to solve the task. Differences encompass performance on button3 of Test day3. The EpRec- and the SeRec-Group were nearly equal accurate on button3 and 2, where as the nRec-Group was better on button3 than on button2. Performance of the EpRec-Group was as expected best, emphasizing the importance of identifying the temporal order rule to solve the task, whereas performance of the nRec-Group on Test day3 might be due to chance.



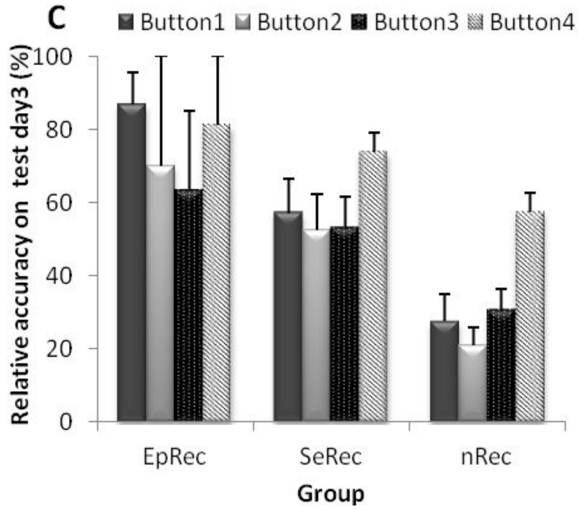


Fig. 14 Relative accuracy on the buttons of the single Test days across the groups on Test day1 (Fig. 14A), Test day2 (Fig. 14B) and Test day3 (Fig. 14C). Notice that button4 was most accurately used followed by button1 in all three groups on all three Test days. Error bars show the standard error of the mean (SE).

Analysis on reaction time

Figure 15A shows mean reaction time of all participants. The ANOVA revealed no significant main effect of the Test day, (F (1.26, 49.18) = 3.34, p = .64). Though not significant, allover reaction times were higher on Test day1 (M = 3393.2 ms, SE = 476.9 ms) than on Test day2 (M = 2628.6 ms, SE = 308.4 ms) and 3 (M = 2682.7 ms, SE = 297.83 ms). Figure 15B shows mean response latencies for correct and incorrect answers, for each single testing day. The ANOVA revealed significant effects of both, the Test day (F (1.49, 53.66) = 7.92, p = .003, η^2 = .180) and Response type (*F* (1, 36) = 9.86, *p* = .003, η^2 = .215) as well as an interaction between Test day and Response time (*F* (1.51, 54.19) = 12.10, *p* = .000, η^2 = .252).

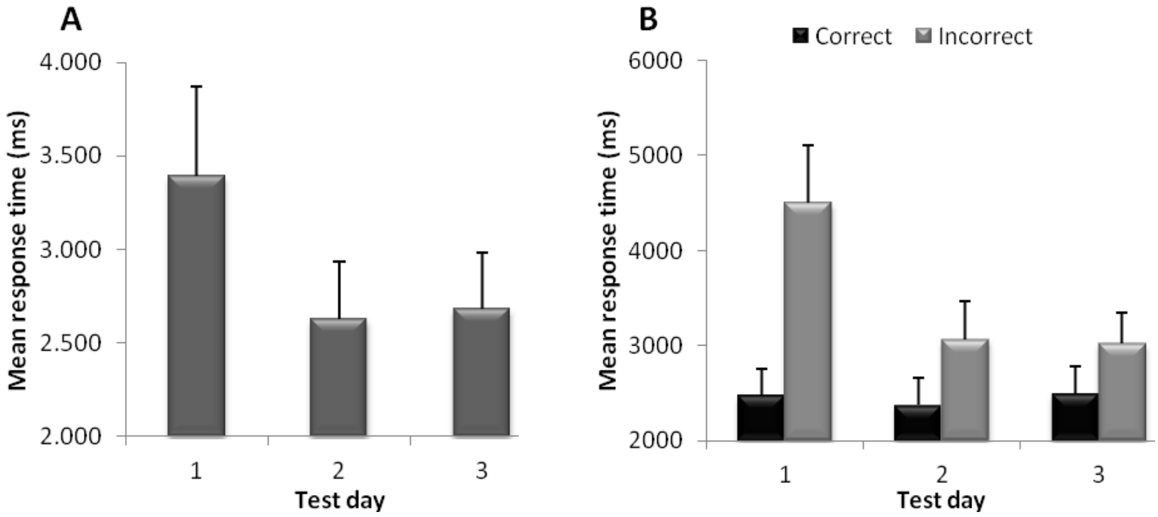


Fig. 15 Mean response time on the single Test days (Fig. 15A) and on correct and incorrect answers on the single Test days (Fig. 15B) of all participants. Participants responded slower on Test day1 and equal fast on Test day2 and 3. Higher reaction latencies on Test day1 resulted from slower reactions to incorrect answers. Error bars show the standard error of the mean (SE).

Overall participants responded faster to correct than incorrect answers, on Test day1, (*t* (37) = -4.58, *p* = .000), Test day2, (*t* (38) = -2.33, *p* = .025) and Test day3, (*t* (37) = -4.81, *p* = .000). At the same time, reaction time for incorrect answers diminished significantly, from day1 to 2, (*t* (37) = 2.30, *p* = .027) and day1 to 3, (*t* (36) = 2.92, *p* = .006) but not from day2 to 3, (*t* (37) = 0.39, *p* = .704). Reaction times of the correct answers did not differ between, Test day1 and 2 and (*t* (39) = 0.60, *p* = .555), Test day1 and 3, (*t* (39) = - 0.16, *p* = .875) and Test day2 and 3, (*t* (39) = -1.70, *p* = .098).

Analysis on reaction times by group

Descriptive analyses on reaction times between the groups (see Fig. 16A) revealed that on Test day1, 2 and 3, the EpRec-Group was faster than either the SeRec-Group or the nRec-Group.

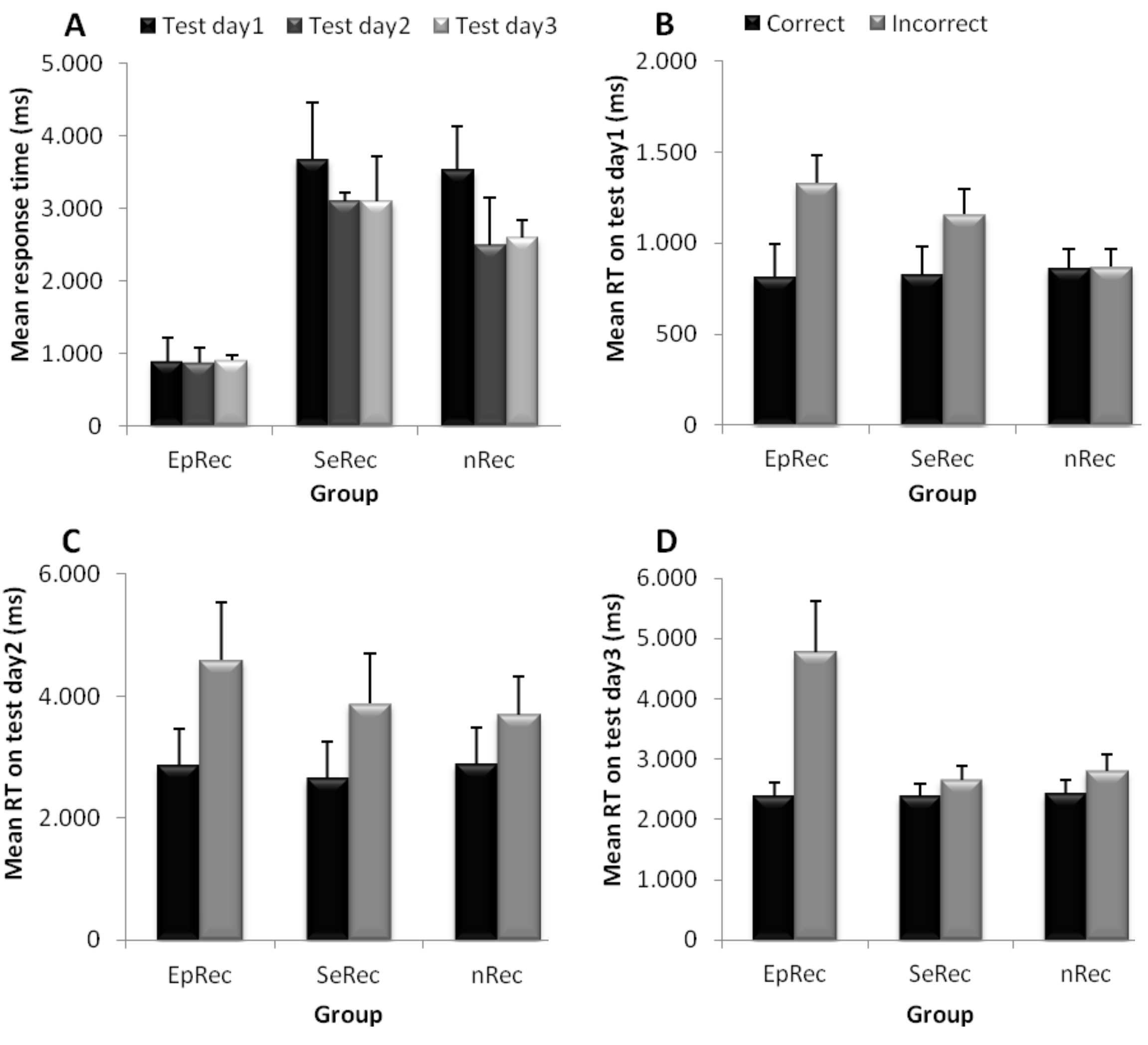


Fig. 16 Mean response time (RT) of the three groups on the single Test days (Fig. 16A) and on correct and incorrect answers on Test day1 (Fig. 16B), Test day2 (Fig. 16C) and Test day3 (Fig. 16D). Participants of the EpRec group responded faster on all Test days. All participants responded faster to correct and slower to incorrect answers. Error bars show the standard error of the mean (SE).

A descriptive analysis on the reaction times for correct and incorrect answers, between the groups, on Test day1 (see Fig. 16B), Test day2 (see Fig. 16C) and Test day3 (see Fig. 16D), revealed that, all groups responses more slowly to incorrect than to correct answers.

2.2.3 Discussion

In experiment 2 we modified our paradigm to investigate whether spatial information and the successive presentation of response buttons facilitates the retrieval of temporal order information. Participants were presented with the spatial configuration of three pictures to facilitate the recall the associated temporal context. The temporal order rule was the same as in the former experiment and could be abstracted by reinforcement.

Taken together, behavioral data indicate that participants on the first and second Test day were more accurate than on the third. The learning curves of all three Test days were ascending and had a steep slope indicating that participants were able to implicitly acquire and apply knowledge about the temporal order rule. But the improvement in accuracy was higher on Test days 1 and 2 than on day3. Performance was least accurate on the third Test day. These results agree with those of the first experiment, in which we attributed this finding to task difficulty. On Test day3, the high number of response alternatives (24) aggravated the abstraction of temporal order rule, resulting in less information gain and thus in lower accuracy. Finding on response latencies were also consistent with those of the first experiment and can be ascribed to increasing familiarity.

Analysis of the accuracy on the buttons seems to support the learning assumption. Participants performed better on button1 and 4 than on the other two, suggesting that they were able to discriminate between the recently seen critical picture sequence and other sequences, implying short term recognition. However, the relative accuracy on button2, on Test day2, and button2 and button3, on Test day3, was moderate and comparably high as on button1, suggesting that long term recognition and recall of temporal order information occurred.

The results indicate that high accuracy could be a result of identifying the temporal context of the critical sequences and the concomitant use of parts of the temporal order rule. But in the verbal disclosure of each Test day the majority of the participants still did not report using the temporal order rule that was needed for correct explicit performance. Rather they either verbalized a semantic or no rule.

On Test day1, only short term recognition of the sequence was required and no temporal order rule was to be abstracted, nevertheless, 2 participants reported using a temporal order rule and performed better than those of the SeRec-Group (n=19) and the nRec-Group (n=19). This advantage is also reflected in the learning curves where the EpRec-Group reached accuracy of 100% on some blocks. This could point to some knowledge of task requirements prior to participation. The faster responses of the EpRec-Group over all three Test days, which also encompassed lower response latencies on correct in incorrect answers, supports the assumption of prior knowledge.

Accuracy trend on Test day2 illustrates a similar performance of the EpRec (n=3) and the SeRec- Group (n=17). The prior knowledge of the EpRec-Group might have prevented information gain, while the SeRec-Group could improve their performance, resulting in the similar performance of both groups.

On Test day3, the acquired knowledge of Test day2 was to be transferred and extended. Because the SeRec-Group (n=17) did not acquire all parts of the temporal order rule, which was necessary to be applied on Test day2, its performance was inferior to that of the EpRec-Group (n=3). The presentation of retrieval cues (What and Where) might facilitate only the implicit recall of temporal order information but we found no evidence for real episodic recollection.

Due to experimental control, participants were required to rely on temporal order as a discrimination cue, ruling out the possible use of time of the day and interval timing to discriminate the spatial location of the pictures. Possibly, these additional cues might contribute to the construction of temporal order and their absence prohibited the construction of such an order on the third Test day. In a further experiment the variation of the temporal cues, used for encoding, could give some disclosure about the contribution of the various temporal cues to the construction of temporal order information.

Furthermore, the omission of the spatial component in the task could increase emphasize on time and facilitate the identification and report of the temporal order rule.

2.3 Experiment 3

In Experiment 2 we asserted that the emergence of temporal order might be an interaction between different temporal cues during encoding. In order to examine this assumption, we varied the temporal cues between two groups. In both groups the experiment was implemented on three successive Test days. Group1 could choose any time of the day to participate and thus could use time of the day, and interval timing as temporal cues. Group2 had to participate at the same time of the day and could rely only on temporal order. Another difference to the second experiment concerned the omission of the spatial component from the task. The pictures were presented sequentially in the encoding and the recognition phase. If interval timing and time of the day contribute to the formation of temporal order in episodic memory, group1 should perform better than group2 on the implicit behavioral and explicit verbal data. If there is a temporal organization by means of order only, group 2 should perform better than group1. If participants of both groups are equally accurate, then temporal organization is assumed to be resulted from temporal order. No emergence of temporal order can be presumed if both groups perform with low accuracy in the behavioral data and demonstrate no knowledge of the temporal order rule in the explicit data.

2.3.1 Method

Participants

27 healthy psychology undergraduates (12 Group1 and 12 Group2), from the Heinrich Heine University, participated in the present study. The mean age of the participants of Group1 (5 females, 83.3 % right handed), ranged between 19 and 41 with an average of 26.6 years (*SD*=7.7) years. The mean age of the participants of the Group2 (6 females, 91.7 %), ranged between 19 and 30 with an average of 23 years (*SD*=3.3) years.

Apparatus & Stimuli

See experiment 2.

Procedure

Participants were randomly assigned to group1 or 2. The procedure was identical to the second experiment except that, the pictures were presented sequentially, each centred on the screen for 5 seconds with an inter stimulus interval of 1 second, in the encoding (see Fig. 17A) and in the recognition phase (see Fig. 17B). The main experiment consisted of three consecutive Test days. While the testing of group1 could be conducted on three consecutive days at varying day times, those of group2 were spaced exactly 24 hours apart.

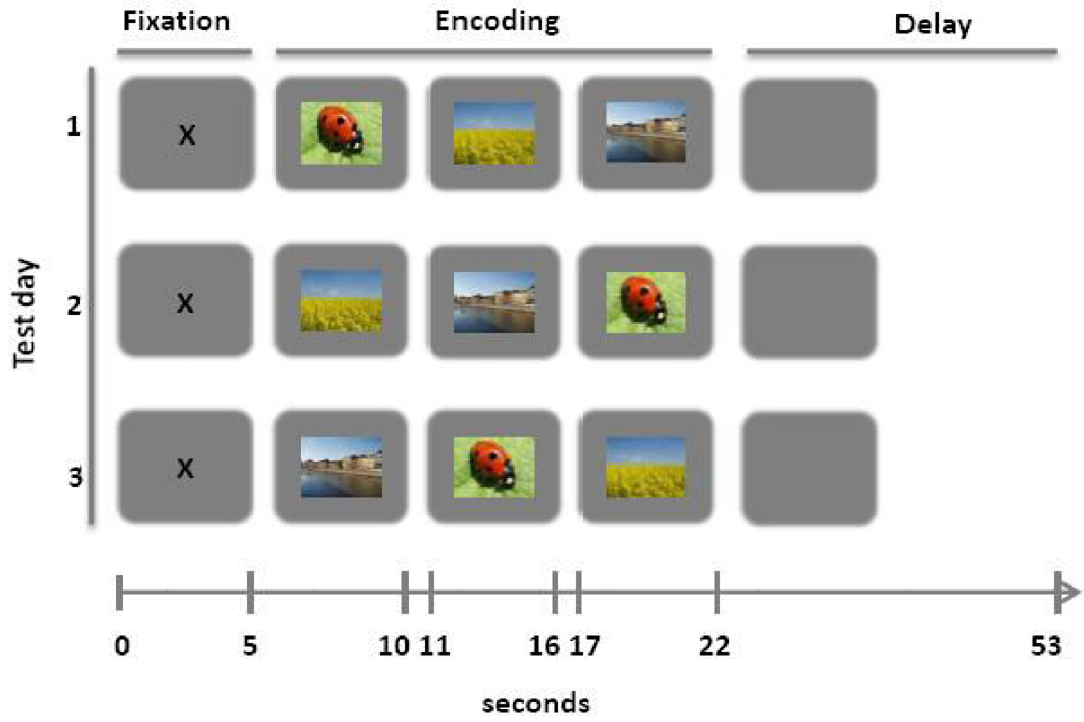


Fig. 17A Illustration of the procedure of the encoding phase in experiment 3.

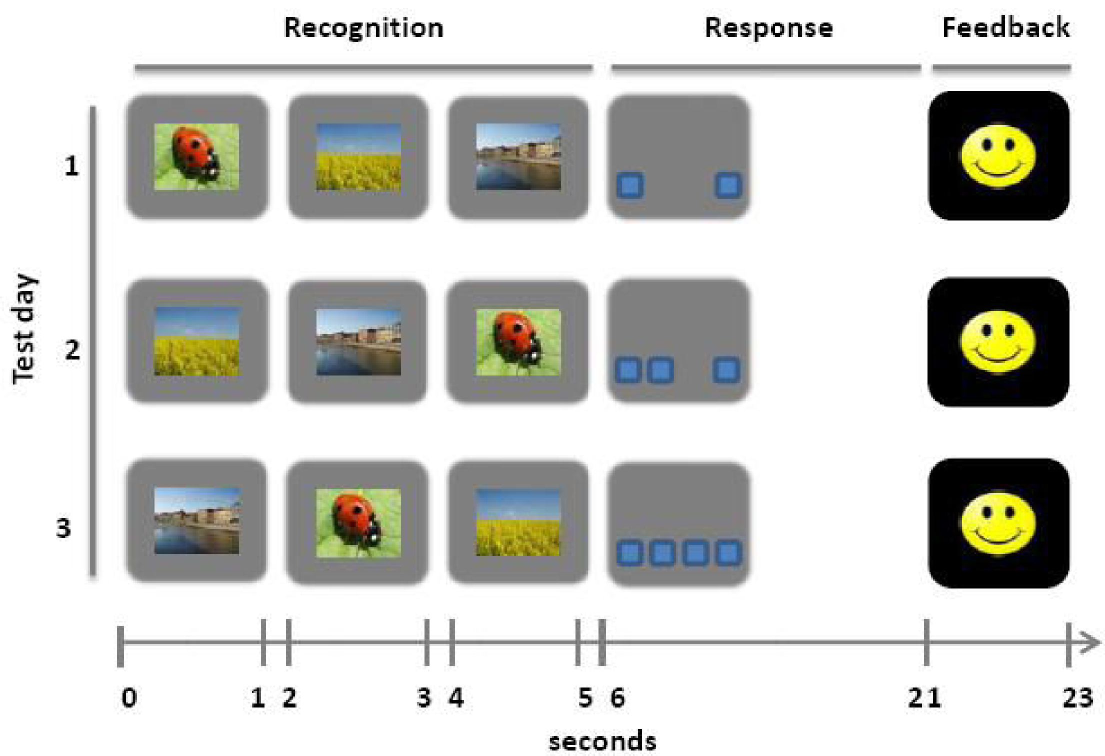


Fig. 17B Illustration of the procedure of the recognition and response phase followed by feedback in experiment 3.

Data analysis

Accuracy (percentage of correct responses) was analysed with a repeated-measures ANOVA, with the within subject factor Test day (1, 2, 3) and the between subject factor group. Relative accuracy was analysed with a repeated measure ANOVA, with the factor button, with 2 levels on Test day1, 3 levels on Test day2 and 4 levels on Test day3. Reaction time (time from button onset to response) was analyzed with a repeated measure ANOVA, with the between subject factor group and the within subject factor Test day (1, 2, 3) or response type (correct, incorrect). Trials with responses later than 15 seconds were defined as incorrect. We used an alpha level of .05 for all statistical tests. Main effects were analyzed using Bonferroni corrected pair wise comparisons. The data from 3 participants (outliers) were excluded from analysis because they did not respond in over 50% of the trials.

2.3.2 *Results*

Analysis on verbal disclusure

On Test day 1, temporal order rule was identified by 0% of the participants. 91.7 % (n=9) of the first and 58 % (n=7) of the second group applied a semantic rule. 25% (n=3) of Group1 and 42 % (n=5) of Group2 did not report any rule. On Test days2 and 3, 16.7% (n=2) of Group1 and 2 identified the temporal order rule, 75% (n=9) of Group1 and 42% (n=5) of the second group applied a semantic rule. 8.3% (n=1) of the first and 42% (n=5) of the second group did not report any rule. The detailed responses of all participants are found in the appendix.

Analysis on accuracy

Mean accuracy rates are shown in figure 18, for Group1 which received time of the day, interval timing and temporal order, and for Group2, which received only temporal order as temporal cue as retrieval cues. Group1 reached a mean accuracy of 78% (*SE* = 4%), on Test day1, 71% (*SE* = 7%) on Test day2 and 66% (*SE* = 9%) on Test day3. Group2 reached a mean accuracy of 70% (*SE* = 5%) on Test day1, 69% on Test day2 (*SE* = 8%) and 66% (*SE* = 9%) on Test day3. No between group differences could be found (F (1, 22) = 0.13, p = .722). Overall, the accuracy rates across the three Test days were not different from one another (F (2, 44) = 1.65, p = .203). No interaction effect was found between accuracy rates across the three Test days and the Group (F (2, 44) = 0.38, p = .688).

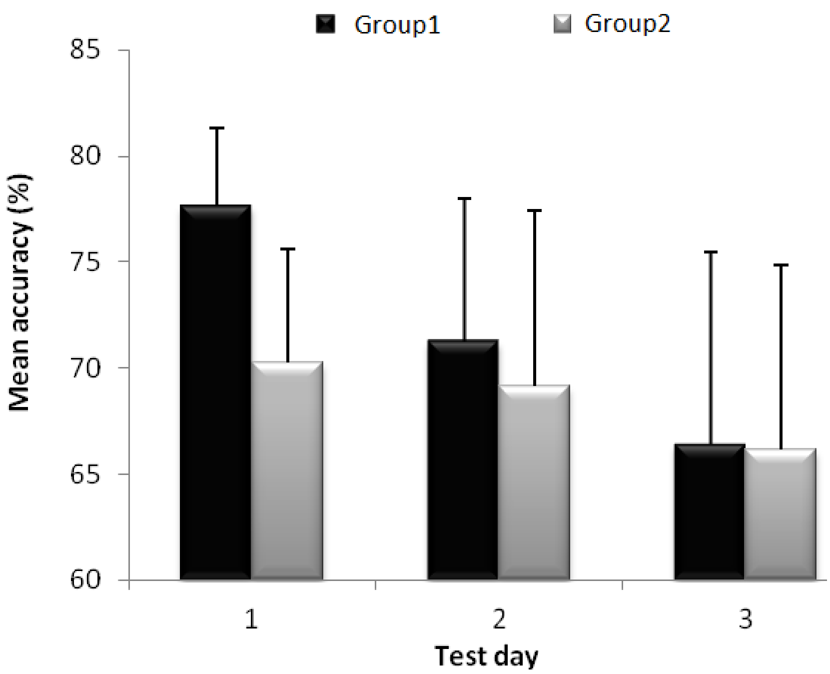
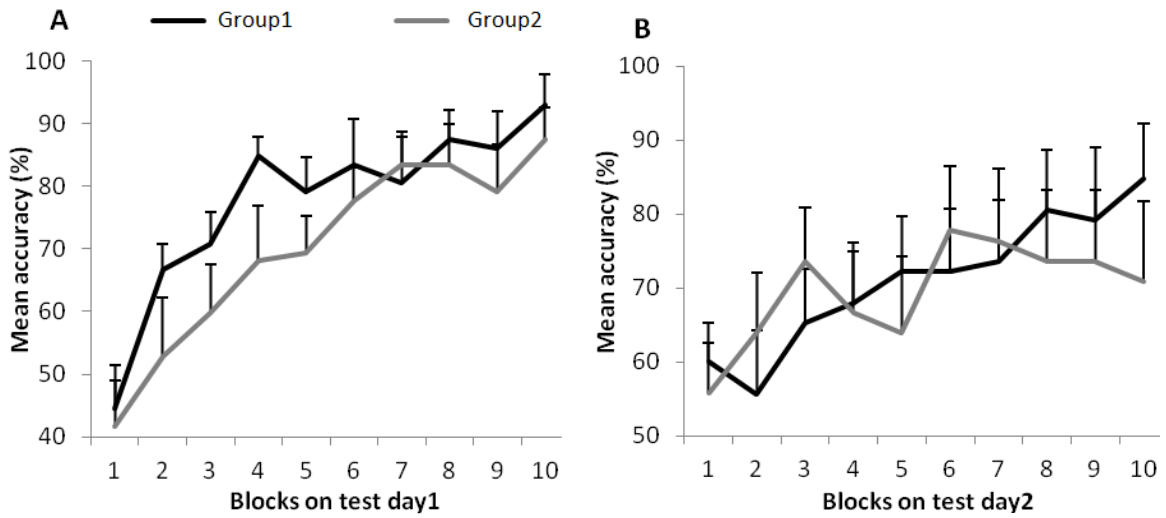


Fig. 18 Mean accuracy on the single Test days for the participants receiving time of the day, interval timing and temporal order as retrieval cues (Group1) and for the participants receiving only temporal order as retrieval cue (Group2). Notice the trend for better performance of group1 on the first two testing days. Error bars show the standard error of the mean (SE).

Accuracy rates across the ten blocks are plotted, separately for the two groups, in figure 19A for Test day1, 19B for Test day2 and 19C for Test day3. The mixed ANOVA revealed a main effect of the factor Block (F (3.23, 72.01) = 24.08, p = .000, η^2 = .523), but no main effect of the factor Test day (F (2, 44) = 1.63, p = .208), no interaction between group and Test day (F (2, 44) = 0.39, p = .679) and no interaction between group and the factor Block (F (9, 198) = 0.47, p = .897).

The within subject ANOVA conducted on the accuracy data, across the Blocks and Test days in Group1 revealed a significant main effect of the factor Block (F (2.36, 25.99) = 12.50, p = .000, η^2 = .532) and an interaction between Test day and Block (F (18, 198) = 1.99, p = .012, η^2 = .153), but no effect of the factor Test day (F (2, 22) = 1.39, p = .269). Post hoc t-test analysis on the interaction effect showed no significant differences on block1 and 10 of the three testing days (all $p > 0.008$). Results of the within subject ANOVA, conducted on the accuracy data of the Blocks, on each single Test day, revealed a significant main effect on Test day1 (F (3.31, 36.41) = 9.74, p = .000, η^2=.470), Test day2 (F (2.31, 25.41) = 4.89, p = .013, η^2 = .308), but not on Test day3 (F (2.87, 31.56) = 2.43, p = .086). Pair wise comparisons revealed that accuracy of Group1 rises significantly from block1 to block 10, on Test day1 (MD = -48.61, $p < .01$) but not on Test day2 ($p > .05$).



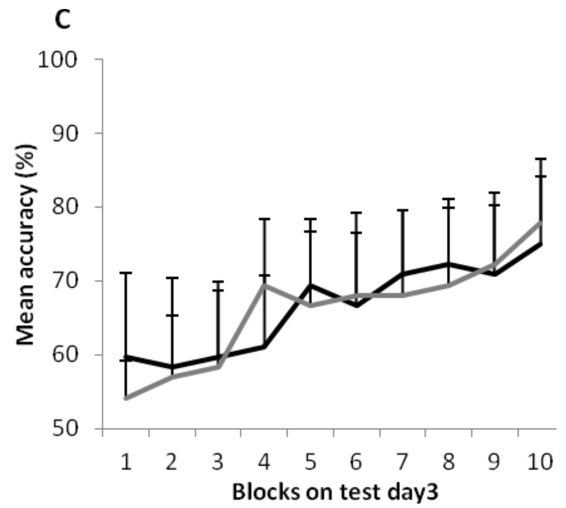


Fig. 19 Mean Accuracy across the 10 blocks on Test day1 (A), Test day2 (B) and Test day3 (C) plotted separately for the group receiving time of the day and serial order as temporal cues (Group1, n=12) and the group receiving only serial order as temporal cue (Group2, n=12). Notice the similar performance of both groups. Error bars show the standard error of the mean (SE).

The within subject ANOVA conducted on Group2 revealed a significant main effect of the factor Block (F (3.12, 34.32) = 12.05, p = .000, η^2 = .523) and an interaction between Test day and Block (F (18, 198) = 2.16, p = .005, η^2 = .164), but no effect of the factor Test day (F (1.16, 12.72) = 3.67, p = .586). Post hoc t-test analysis on the interaction effect showed no significant differences on block1 and 10 of the three testing days (all $p > 0.008$). Results of the within subject ANOVA revealed a significant main effect on Test day1 (F (9, 99) = 9.81, p = .000, η^2 = .471), Test day2 (F (3.79, 41.71) = 2.98, p = .032, η^2 = .213) and on Test day3 (F (2.83, 31.14) = 3.10, p = .043. η^2 = .220). Pair wise comparisons revealed that, accuracy of Group2 rises from block1 to block 10, on Test day1 (MD = -45.83, $p < .05$), but not on Test day2 and 3 ($p > .05$).

Analysis on behavioral button responses

Relative accuracy on the single buttons of the testing days is shown, in figure 20A for Group1 and in figure 20B for Group2. On all three testing days no group effect and no interaction between Group and the factor Button could be found (p > .05). On Test day1, relative accuracy varied across the buttons, (F (2, 22) = 22.50, p = .000, η^2 = .51), in Group1, (F (1, 11) = 13.96, p = .003, η^2 = .56) and Group2 (F (1, 11) = 8.69, p = .013, η^2 = .44), where relative accuracy on button4 was higher than on button1.

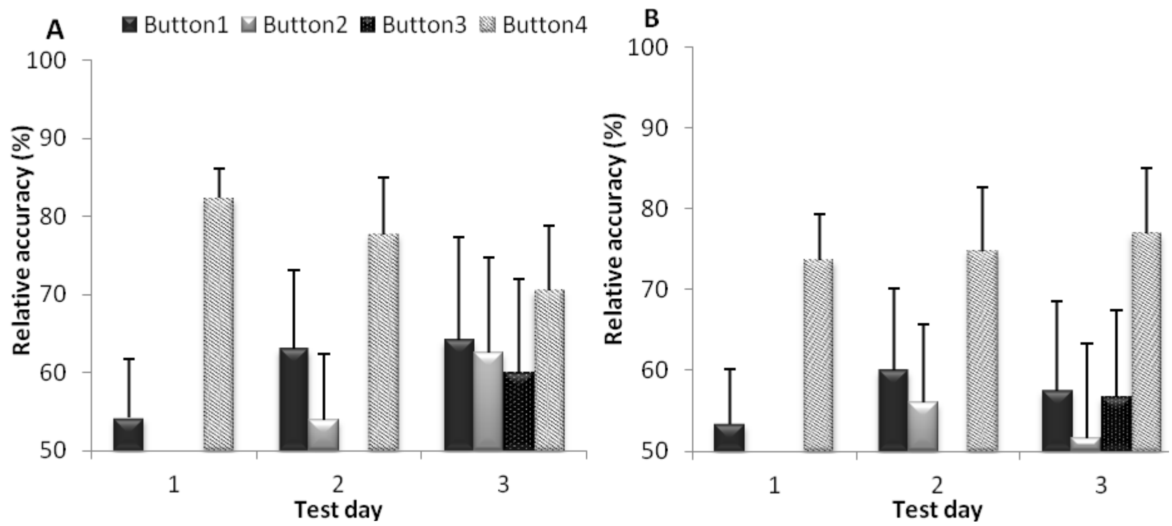


Fig. 20 Mean accuracy on the buttons of the three Test days for the group receiving time of the day, interval timing and temporal order as cues (20A) and the group receiving only temporal order as cue (20B). Performance of both groups is similar. Error bars show the standard error of the mean (SE).

On Test day2, a main effect of the factor Buttons (F (2, 44) = 8.81, p = .001, η^2 = .29) was found in Group1, (F (2, 22) = 3.65, p = .043, η^2 = .25), and Group2, (F (1.32, 14.5) = 6.60, p = .016, η^2 = .25). Pairwise comparisons revealed no significant differences in accuracy across the buttons (all p > .05) in Group1. In Group2 relative accuracy on button4 was found to be higher than on button1 (MD = -19.96, p = .01) and button2 (MD = -14.79, p = .007). On Test day3, relative accuracy data revealed a main effect of the factor Buttons (*F* (3, 66) = 3.37, *p* =.024, η^2=.13), found in Group2, (*F* (1.76, 19.4) = 3.93, *p* =.041, η^2 =.26), where relative accuracy on button4 was higher than on button2 (*MD* = -25.28, *p* = .03) and button3 (*MD* = -20.28, *p* =.041), but not in Group1 (*F* (2, 22) = 3.65, *p* = .043).

Analysis on reaction time

Mean reaction time of the each Test day, is shown in figure 21, for Group1 and 2. Reaction time of Group1 was on Test day1 (*M* = 3827.8 ms, *SE* = 717.7 ms), slightly higher than on Test day2 (*M* = 3507.3 ms, *SE* = 677.4 ms), and 3 (*M* = 3618.1 ms, *SE* = 721.4 ms). Group2 responded slower, on Test day1 (*M* = 5190 ms, *SE* = 787.4 ms), 2 (*M* = 4738.3 ms, *SE* = 753.5 ms) and 3 (*M* = 4686.9 ms, *SE* = 744.5 ms). The ANOVA showed no effect of the factor Test day (*F* (1.17, 25.64) = 3.23, *p* = .077) and no interaction between Test day and the Groups (*F* (1.17, 25.64) = 0.38, *p* = .57). The between subject factor Group was also not significant (*F* (1, 22) = 1.43, *p* = .24).

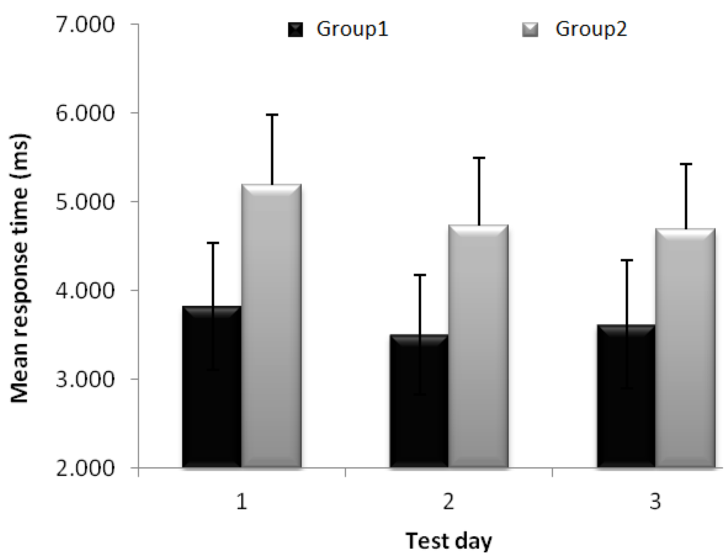


Fig. 21 Mean reaction time on the single Test days for the group receiving time of the day and serial order as temporal cues (Experimental) and the group receiving only serial order as temporal cue (Control). Notice the trend for faster response times in the experimental group. Error bars show the standard error of the mean (SE).

Figure 22 shows mean response latencies for correct and incorrect answers in Group1 (A) and Group2 (B). All participants responded faster on correct than incorrect answers on all Test days. The ANOVA revealed no main effect of Group (F (1, 18) = 0.52, p = .479), no significant main effect of Test day (F (1.29, 23.38) = 1.44, p = .251), and no interaction between Test day and Group (F (1.29, 23.38) = 0.02, p = .945), Response type and Group (F (1, 18) = 0.22, p = .64), Test day and Response type (F (1.47, 26.4) = 2.18, p = .114) and Test day, Response type and Group (F (1.47, 26.42) = 0.27, p = .69). On all three Test days no effect of Group and no interaction between Group and the factor Button could be found (p > .05).

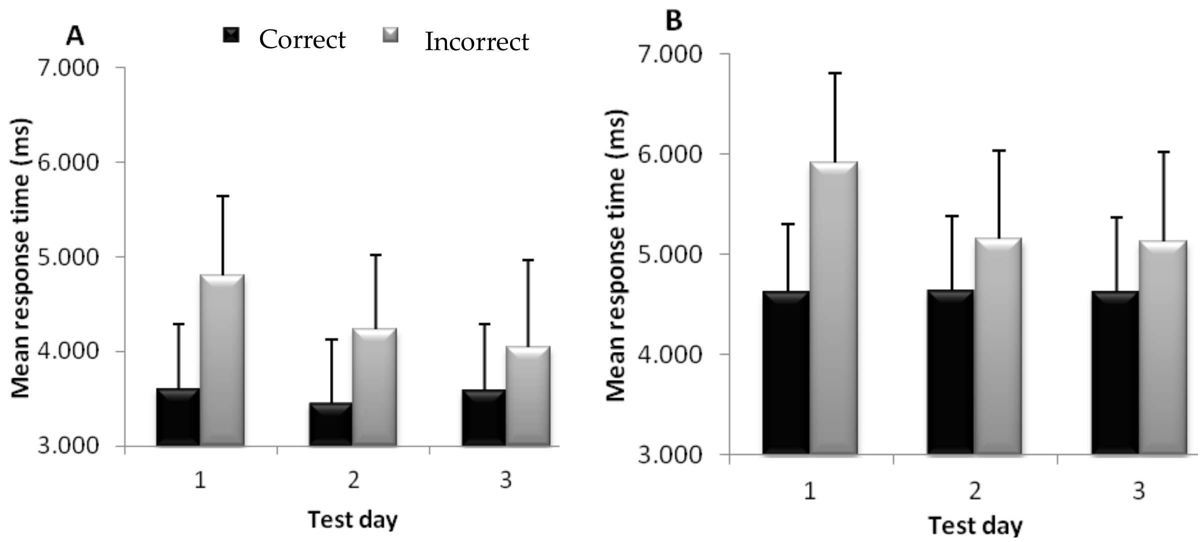


Fig. 22 Mean reaction time for correct and incorrect responses on the three Test days for the group receiving time of the day and serial order as temporal cue (22A) and for the group receiving only serial order as temporal cue (22B). Both groups responded faster to correct than to incorrect answers. Error bars show the standard error of the mean (SE).

Differences in reaction time to correct and incorrect answers were found to be significant (F (1, 18) = 17.75, p = .001, η^2 = .49). The data show that, Group1 responded significant faster to correct than to incorrect answers on Test day1, (t (11) = -4.07, p = .002) but not on Test day2, (t (11) = -1.96, p = .076) and 3, (t (7) = -1.53, p = .171). Participants of Group2 responded significant faster to correct than incorrect answers, on Test day1 (*t* (11) = -2.12, *p* = .05) and 2 (*t* (11) = -2.77, *p* = .018) but not on Test day3, (*t* (11) = -1.74, *p* = .109).

2.3.3 Discussion

In experiment 3, we increased the emphasis on time and varied the encoded temporal cues in Group1, while Group2 was allowed to rely only on temporal order to retrieve the associated temporal context.

No differences in accuracy and information gain between the groups were found, implicating no variable learning behavior. All Participants showed high accuracy over the Test days with a declining trend from Test days1 to 3. Both groups improved accuracy over the blocks, more on Test day1 than on 2, while on Test day3 performances remained constant. Declining performance over the Test days was found in both groups and was probably due to increasing task difficulty.

No group differences were found in the accuracy data among the buttons. On all Test days, participants were highly accurate on button4 and button1. These results suggest that, the critical picture order was distinguished from the others. Participants assigned the former to the first button and the later to the fourth button, indicating recognition of the recently seen picture order on all three Test days.

On Test day2 and 3, a trend to a differential behavior between the groups could be observed. While on Test day2 and 3, relative accuracy in Group1 did not vary across the buttons, participants of Group2 demonstrated a different behavior. Accuracy of Group2 on button2 of Test day2 and 3 and button3 of Test day3 was moderate. This could be an indication of the recognition of the picture order seen a day or two previously.

Response times of both groups were comparably high and did not vary across the Test days. Nevertheless, a trend was observed towards lower response times in Group1 and this trend was also found in the differential response times for correct and incorrect answers in both groups. The finding that participants responded faster on correct than incorrect answers might underline the recognition of the critical sequences that were matched with more confidence to the right buttons.

The hypothesized over-performance of the experimental group was absent in the data, even though a trend in this direction was observed. The same performance of both groups on this task indicates that the additional temporal cues given during encoding did not prompt recognition of order and the recall of the temporal context. While on Test day1 these cues were not expected to influence performance, since participants had only to distinguish the recently encoded order from the others, they were expected to facilitate recognition on Test day2 and, particularly, on Test day3, where the associated temporal context of the last two days had to be recalled.

However, responses on the verbal disclosure were indicative for a non-episodic recall, since the majority of the participants did not verbalize the temporal order rule. The findings are in line with research on human memory which could not find evidence for an automatically temporal encoding (Friedman, 1993, 2004, 2007) but contradicts research results on animal models, suggesting that animals encode and retrieve temporal cues (Clayton & Dickinson, 1998, 1999b; Clayton, Griffiths, Emery, & Dickinson, 2001; Martin-Ordas et al., 2010; Roberts et al., 2008; Roberts & Roberts, 2002).

3. General discussion

The aim of the present work was to develop an experimental approach that can be used, with some modifications, across different species and controls for temporal confounds. In order to assess the retrieval of temporal order information non-verbally, we replaced instructions by associative learning. In a series of three experiments we examined whether participants learn to apply a temporal order rule and whether the acquired knowledge can be intentionally accessed and reported.

Events of our daily life, such as encounters with friends and colleagues, and also special occasions, like graduation or the birth of a child are stored in ´episodic memory´. This memory system contributes to the formation of our own subjective history and autobiography, which is organized on a time line. It enables us to travel mentally to a defined time span in order to relive a specific individual episode in the present, with the conscious awareness that this episode occurred in the past. Mental time travel is said to be the milestone in the evolution of language. Corballis (2009a, 2009b) states that humans started enlarging their vocabulary, in order to communicate and share their mental time travel to the past. Allen and Fortin (2013) determined some basic functions of episodic memory, which are said to be common across all species - making memory based predictions, scheme plans for a distant future and development of social networks.

Non-human animals possess a similar kind of memory, termed ´episodic-like memory´, with emphasis on the behavioral criteria underlying its definition by means of remembering the spatio-temporal configuration of unique events. Corballis (2009a) envisages the evolutionary benefit of this memory system in its contribution to the individual fitness of the tested species. Scrub jays adapt their caching behavior in anticipation of potential future needs (Clayton, Bussey, et al., 2003; Correia et al., 2007). Meadow voles remember the location of a female vole in her highest state of sexual receptivity (Ferkin, Combs, delBarco-Trillo, Pierce, & Franklin, 2008). Apes choose and save appropriate tools crucial to future needs (Mulcahy & Call, 2006). All these finding are indicative for adaptive behavior, which is in the present applied in order to benefit from it in the future. This indeed increases the possibility of survival.

Episodic memory is today defined in terms of phenomenal criteria accompanying the recollection process such as the self, autonoetic awareness and mental time travel. These mental experiences can be assessed best verbally. Presently, no objective quantitative measure has been found to substitute the verbal report of the subjective mental experience. In human studies this state is questioned after employing a recall or recognition paradigm (Holland & Smulders, 2011; Tulving, 1983). In the comparative field, two influential models, named the caching paradigm and the novelty preference paradigm, were developed to assess the behavioral features of episodic memories (Clayton & Dickinson, 1998; Dere et al., 2005a). While almost all non-human studies consistently reported recall of 'What and Where' features, findings on the 'When' component were inconsistent (Hampton et al., 2005; Hampton & Schwartz, 2004). This possibly is due to confounding in the temporal component, which is not objectively operationalized and controlled (Roberts et al., 2008).

The temporal aspect of episodic memory is emphasized in the current and preceding definition of episodic memory, suggesting an underlying temporal organization, which could be based on distance, location or order (Tulving, 1972, 1983, 1984, 1993, 2001, 2002, 2005). Research conducted on humans could not find evidence for an automatic encoding of time, as proposed by the time tagging theorie (Friedman, 1993, 2007). Instead, the time in which an event occurred seems to be rather reconstructed by mentally traveling to the relevant episode and using temporal markers (natural or acquired) as a guide to infer the temporal context (Friedman, 2007).

In a different approach, psychologists assessed episodic-like memory in humans, using comparative methods, in order to understand the timing mechanism involved in temporal reconstruction (Babb & Johnson, 2010; Easton et al., 2012; Holland & Smulders, 2011; Pause et al., 2010). Most of these studies did not control for the confounding of temporal cues and used instructions to model behavior which, on the one side, promote the involvement of semantic memory and, on the other side, reduce comparability to non-human animals.

3.1 Findings on behavioral data

In the first experiment, results revealed moderate accuracy on all three Test days. In the second experiment, participants demonstrated high accuracy on day1 and 2 and moderate accuracy on day3. In the third experiment, high accuracy rates were found on all three Test days. We suggested that improvement in implicit performance resulted from reduction of task difficulty from experiment 1 to 2 and from increasing emphasize on the temporal aspect of the task from experiment 1 and 2 to 3. In all three experiments, accuracy increased from day 1 to day2 and decreases from day 2 to day 3. Increase in accuracy from day 1 to 2 was ascribed to reduced uncertainty considering task requirements, while the decrease in accuracy from day2 to 3 resulted from the high amount (24) of to be tested picture sequence-buttons associations. Furthermore, accuracy on button 4 and 1 was best in all experiments underpinning that this performance was based on old-new judgments. In experiment 2 and 3, accuracy on button 2 and 3 was moderate and thus indicative for the reconstruction of temporal order. In all three experiments the minority of the participants could verbalize the temporal order rule on day2 and 3, while the majority reported either having applied a semantic or no rule.

Three main findings arise from the conducted studies. First, cognitive inference from temporal to spatial configurations aggravates recognition and increases cognitive load. Second, the presentation of additional spatial cues and successive presentation of response buttons improves implicit performance. Third, increasing emphasizes on temporal order, by means of sequential presentation of the pictures in the encoding and recognition phase, improves implicit performance. But none of these manipulations enhanced verbalization of the temporal order rule. We could measure the retrieval of temporal information, when instructions were replaced by reinforcement and found that the retrieval process was a product of non episodic associations. Without insight to the necessity of temporal encoding or the intention to use conventional time pattern, episodic recollection seems not to be involved. However, these findings are to some extent surprising, since one would expect that humans, who are known to possess episodic memory, would be able to identify day to day changes. Prior to an explanation of this counter-intuitive finding, one has to regard the experimental procedure from the perspective of the participants, in order to be able to understand their performance. In all three experiments, participants were seated in front of a computer screen and told that they would have to figure out task requirements, without getting verbal instructions. Immediately after the experimenter started the task, a fixation cross appeared. Participants must have been aware that some important information must be coming, to which they were supposed to attend. The presentation of the three pictures confirmed this assumption, but still they could not know what exactly required their attention. At that time, they could have attended only to the pictures.

After that the delay phase was initiated and they saw a black screen, some of the participants touched the mouse trying to achieve a response, without getting feedback on the performed action. Other participants watched only the black screen, anticipating what would happen next. Initiating the response phase the same three pictures, presented earlier, were seen. The first presented picture sequence could have been identical or different to the sequence of the encoding phase. Participants had to decide what was different. Some of them might have proceeded in observing the perceptual features and, by the time the sequence disappeared and the response buttons were displayed, they performed an action, using the mouse, and identified the buttons as response surfaces. This response was followed by an immediate feedback which could be either positive or negative. At this time no hypothesis about an associative rule could have been built. By contrast, the participants, who kept observing the perceptual features, were not aware of the necessity to perform an action; they ignored the buttons and, after 10 seconds, they heard a buzzer. This buzzer was either interpreted as instigation to respond or as a punishment they had to bear while being tested for frustration tolerance. By no later than the beginning of the second block all participants identified the buttons as response tools and first sequence buttons associations were tested. This explorative behavior revealed that most of the picture sequences associated to button4 seemed to be correct while button1 was correctly associated to one picture sequence only. Most of the participants realized that the initial sequence was to be classified from the others. A minority assumed a memory task, in which they have either to memorize all the presented picture sequences, or all the orders in which the pictures occurred. Some used the positional information of a certain picture as an anchor to associate it with the position of the buttons. Still others reported simply not to know requirements or predicted the absence of a specific rule and assumed a complot to measure frustration tolerance and stress level.

On the second and third Test day, participants undertook the same procedure. This time, they started with the knowledge that they had acquired on the previous Test day - higher success probability when pressing button4. This knowledge was only partially applicable to the second and third Test days since previously unrewarded buttons were rewarded. Two new associations were to be found for the new buttons encouraging the generation of new hypotheses. While button1 was correctly served on the previous day, the same hypothesis did not seem to apply for the current day. Instead, the picture sequence correctly associated to button1, on Test day1, was, on Test day2, associated with button2 and, on Test day3, with button3. The number of picture sequences correctly associated to button4 decreased with the subsequent Test days. This gave rise to the development of a further hypothesis about the underlying rule.

Analysis on behavioral data suggests that participants implicitly learned the association between the picture sequence, temporal context and the buttons. The acquired implicit knowledge was not reported and most of the participants insisted on their previous assumptions, even though this hypothesis did not seem to apply to the current day. This raises the question of what explains the discrepancy between the influence of temporal order in the accuracy data and the close to total lack of insight in the post-session reports.

A possible explanation is that, in the conducted series of experiments, participants were neither prospectively nor retrospectively requested to memorize or reconstruct the temporal order of the pictures (sequence/configuration). The whole task was based on implicit learning of a temporal order rule which, at the end of the task, was to be verbalized. S. W. Brown and Smith-Petersen (2014) suggest that ordering a sequence of events depends on the establishment of explicit temporal relations between the items of this sequence. Explicit time adjectives, such as, before, after, today and yesterday, facilitate the construction and reconstruction of temporal order. The omission of instructions in our design seems to have led most participants to omit these explicit time patterns. This in turn may have made our participants search for a semantic rather than a temporal rule. Hence they were not aware of the importance of time; attention was focused on other features.

An alternative interpretation is based on the hypothetical distinction between episodic-like and episodic memory in humans. While the former can operate with the anoetic form of awareness, the latter presumes autonoetic awareness. Episodic-like memory is likely to be the precursor of episodic memory. In humans basic features, such as storage of the temporal context, regressed in favor of the development of more complex abilities, such as, mental time travel. Retrieval processes in episodic like-memory are unconscious, but real episodic memories cannot be recollected without intention. Temporal reconstruction presumes a high amount of attentional resources, which participants failed to mobilize in our studies, due to the absence of insight mediated intention. This would explain why the participants had no conscious access to the temporal component of the experimentally induced episodic-like memories but still were able to achieve high accuracy.

3.2 Methodological constrains

Even though the above listed explanations seem plausible, it cannot be excluded that possible confounding factors such as, divided attention, task difficulty and interference might have distorted performance. These will be discussed below.

3.2.1 Divided attention

Attention to time increases salience or impact of temporal cues and determines to what extent they will be processed. The test design required focusing attention on several aspects of task requirements. In the encoding phase, participants might have focused their attention on certain features of the pictures. In the recognition phase, attention focused on finding differences to the previously seen pictures and, in the response phase, they were supposed to recognize the necessity to perform a motoric response using the computer mouse and to identify the presented buttons as response buttons. Within the feedback, attention was focused on generating and testing hypotheses about the picture-buttons-associations. Distracting attention away from temporal encoding and recall toward identification of task requirements reduced attention to time. S. W. Brown (1997) examined the influence of divided attention on a temporal judgment task. He compared performance under single versus dual task conditions. In the single task conditions, participants were instructed to attend to the passage of time only and, in the dual task condition, they performed simultaneously a distraction task. He found that performance in the dual task condition was less accurate as in the time single task condition and suggested that error rates in duration judgments are a function of distracted attention. A consequence of divided attention in our experiments is that time was processed superficially, perceived subliminally and, thus, inaccessible to consciousness. As a result incorrect answers worsened with the increase in the amount of attentional resources spent exploring task requirements.

The focus of further study should be to increase the attentional focus on the temporal task. A practice trial, prior to the start of the experiment, in which participants can acquire information about the non-temporal task, can reduce uncertainty and increase confidence. This would disengage attention from the concurrent task and mobilize more attentional resources towards temporal processing.

3.2.2 Task difficulty

Research on temporal processing demonstrated that timing performance is increasingly impaired as a function of increasing task difficulty (S.W. Brown, 2008; S. W. Brown & Merchant, 2007). In our task, difficulty increased with the successive Test days. Because participants were not given any instructions they were requiered to explore task requirements. First they had to determine the necessity to respond and how the displayed blue buttons are to be served, using the computer mouse as tool. Second they were supposed to explore the function of the buttons by permanently generating hypotheses about the button-sequence association and test these relying on reinforcement patterns, until the buttons were identified as temporal markers for the encoded picture sequences. While on Test day1, 12 button-picture associations were to be repeatedly tested on day 2 and 3, they increased to 18 and 24 respectively. Participants were more engaged in identifying the button that provided positive reinforcement. Consequently, the cognitive processing, demanded by the task of each Test day exceeded the cognitive resources of our participants. As a result, reconstruction of temporal order was increasingly impaired from the first to the last Test day.

The attention of further study should be on the reduction of the difficulty of the temporal task in order to decrease cognitive load. The implementation of breaks, between the single recognition trials or blocks, enables reconsideration of the former and the generation of new hypothesis. Furthermore, processing of temporal information should be more efficient, when participants are given the possibility to control their own learning pace.

3.2.3 Retrieval induced forgetting

Previous research has shown that the retrieval of an item from long-term-memory can impair the retrieval of another related item. This effect is known as retrieval induced forgetting and was first introduced by Anderson, Bjork, and Bjork (1994). In most studies participants are asked to memorize a categorized item list. After study they repeatedly retrieve half of the items. Results on a cued recall test revealed that the repetitive retrieval of the practiced items impairs recall of the unpracticed items. Successful retrieval of the target event requires suppression of similar and related events which compete with the target. As a consequence memory for the subsequent event is impaired. (Anderson et al., 1994; Ciranni & Shimamura, 1999; Dehli & Brennen, 2009). This effect has also been demonstrated in episodic memory, using visuo-spatial material (Ciranni & Shimamura, 1999).

The first critical picture sequence was seen during the encoding phase of Test day1. By the end day´s session, participants had seen the critical picture sequence 6 times. Retrieval practice might have improved recognition of this particular picture sequences on the second and third Test day. At the same time, it caused the suppression of the related information, which, in this case, is the picture sequence seen on the current Test day (retroactive interference). Another possible explanation is that the newly encoded picture sequence interfered with the one learned the previous day and caused its forgetting (proactive interference). In avoidance of interference between the retrieved picture sequences of the three testing days, we recommend the employment of different pictures on each Test day. Even though this modification should decrease task difficulty, one must consider that the identity component (What) is also modified and cannot be controlled, ruling out the pure retrieval of the temporal component.

3.2.4 Temporal and ordinal pattern

The long retention interval used between the subsequent Test days is a further concern in our design. Arguments for choosing a long retention interval were referenced by Tolentino, Pirogovsky, Luu, Toner, and Gilbert (2012). They could demonstrate that temporal order memory was lessened as a function of the decrease in temporal distance between two subsequent stimuli, suggesting that long retention intervals might enhance memory for temporal order. Additionally, research on humans could demonstrate that sleep not only facilitates the consolidation and long-term storage of events but also enhances the temporal structure, thus aiding recall (Drosopoulos, Windau, Wagner, & Born, 2007; Gais & Born, 2004; Griessenberger et al., 2012; Walker & Stickgold, 2004). These arguments seemed consistent with the proposals of the temporal isolation effect, predicting enhancement of recall for items spaced in time (G. D. A. Brown, Morin, & Lewandowsky, 2006; Lewandowsky, Nimmo, & Brown, 2008).

Arguments against long retention intervals were provided by the attention shift model. G. D. A. Brown, Neath, & Chater (2007) posit that attention shuttles between a temporal and an ordinal pattern. Temporal patterns are a product of varying the length of time intervals between subsequent events and ordinal patterns are formed through varying categorical variables between subsequent events, like position. While focusing attention towards the temporal dimension will produce the temporal isolation effect, focusing attention on the ordinal dimension will not. In order to discriminate between the picture sequence of today and the one they had seen a day or 2 days before in experiment 1 and 2, participants could use both temporal and ordinal patterns. Furthermore the discrimination of the picture sequences seen yesterday and two days ago is based on encoding ordinal patterns, because participants were not aware of the temporal task, making the decay of memory trace due to the long inter trial interval a possible explanation for the moderate accuracy. In experiment 3, however, only the temporal pattern could have been used, predicting the improvement of recall of the temporal information, which was found.

3.3 Findings on verbal disclosure

In contrast to task performance, the written report of task rule gave little if any evidence of cognitive insight in the majority of the participants. In order to exclude potential biasing factors, like rule induction, participants received at the end of each Test day only one open question, in which they were asked to write down their assumptions about task requirements. The phrasing of the question was meant to access implicit knowledge, without giving participants hints about the procedure and task requirement. Verbal responses on the questionnaire revealed no evidence of awareness of the contingency between the picture sequences, the associated time and the feedback, in most of the cases. Although they reached moderate to high accuracy, they were unable to verbalize the temporal order rule. Participants seemed unaware of the temporal aspect of the task.

If awareness is reflected in the verbal reports on the inferred task rule, the moderately successful performance suggests that participants implicitly learned the temporal order rule. The retrieval process of the associated temporal context did not require conscious access to stored information. Thus, associations between an event and its time of occurrence can be formed, dissociated from awareness, and, in this manner, can influence behavior. This puts in question the proposed unique quality of episodic memory, its specific relation to time. Temporal processing seems not to be a process which is limited to episodic memory, but is also found in more primitive memory systems. However, we cannot exclude the possibility that not all conscious knowledge was reported. Participants could have withheld some information because they either were not confident in their answer or because of being insufficiently motivated. To avoid this problem in a further study, participants should be required to report a certain number of conceivable assumptions in order to receive their incentives.

Otherwise, one could argue that participants did not try to acquire knowledge, but instead focused on gathering coins by consistently pressing the fourth button. In this manner they learned to associate most of the picture sequences to the fourth button. But, with the increasing number of response buttons, the possibility of correct responses to button4 decreased. Participants were forced to revise this strategy, and generate and test new contingencies. This behavior could be observed in experiment 3, where accuracy, on the third Test day, was still high; indicating that the temporal order rule was implicitly learned.

We suggest that the distinction between accessibility of knowledge and expression ability might give a further possible explanation to our explicit data. Reporting implicit knowledge presumes also the ability to verbalize this acquired knowledge. Given that this knowledge was accessible, participants might have experienced difficulty in articulating this abstract rule. It is possible that the available information was insufficient for phrasing, leading, in combination with the above mentioned low confidence in their answer, to no, incomplete or distorted answers on the verbal questionnaire.

3.4 Contribution of Language

One interesting issue concerning episodic memory might be its relation to language generally and to conventional time patterns specifically. (Tulving, 2005) claimed that operations of episodic memory are independent of language or other symbolic systems. Suddendorf and Corballis (2007) criticized this conclusion and postulated that future and past episodes can only be reconstructed under the involvement of semantic knowledge. In response thereto, Friedman (2007) agrees that the time of past events is inferred by relating the content of this event to semantic knowledge about time patterns that can be personal, conventional or natural.

The temporal context of an event can be reconstructed relying on biological time patterns, such as the circadian clock. This internal pacemaker is synchronized by external time cues, such as the light-dark-cycle, seasonal and temperature changes but also social interactions. Indeed humans share this circadian rhythm with non-human animals, allowing both to make time judgments on a rough scale (long vs. short). Uniquely human is the employment of conventional time patterns that enabled more subtle distinctions. These refer to culturally defined and semantically acquired verbal descriptions used to estimate and quantify a point on the time line. Temporal adverbs have been developed and are used to describe points in time (yesterday, today, tomorrow), frequencies which could be definite (monthly, weekly, yearly) or indefinite (always, rarely, never) or in order to express relationships in time (before, later, recently). These time concepts are acquired in the early stage of development when children get engaged in conversations about the past and learn to describe previous experience using temporal adverbs (Eisenberg, 1985). The comprehension and production of simple temporal adverbs improves but still is inaccurate between the ages of 4 and 5, and at the age of above 8 years, time measurement and cyclic aspects of the calendar are mastered (Friedman & Lyon, 2005).

We propose that biological and natural time cues contribute to the formation of implicit temporal associations, while semantically acquired time pattern contribute to the formation of explicit temporal contingencies between events. Our participants implicitly applied the temporal order rule and this learning performance was ascribed to non-episodic associations. Still they were not able to verbalize the acquired knowledge. Conscious access to and verbalization of the time of the reconstructed episode presumes access to semantically acquired time pattern. Lack of insight into the temporal aspect of the task prohibited conscious access to these time patterns and restricted verbal performance.

4. Conclusion

Our data suggest that the retrieval of temporal order information is possible when instructions are replaced by reinforcement, resulting from exploratory button presses. Participants were highly accurate in differentiating between the recently encoded picture sequence and the others and moderate accurate recognizing the picture sequences seen a day or two days ago. Answers on the explicit questionnaire revealed that the retrieval process is a product of non-episodic associations, suggesting no or little involvement of episodic recollection. The reconstruction of the temporal context associated to an event is an intentional process, probably made possible by the development of conventional time patterns. Temporal concepts in human memory might have become noetic and related to awareness because humans need semantically acquired time patterns, in order to verbally describe recollected past events. In non-human animals this timing mechanism evolved distinct from linguistic aspects but could probably be related to non-verbal communication skills, which still cannot be assessed by humans, because of the lack of valid studies an operationalization of these skills. In further studies researchers may want to focus on finding and understanding equivalence to the human communication system in other species and use this system to find an operationalization for the report of the temporal component in episodic memory.

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Experiment 1

Responses on the verbal disclosure

EHM17	Test day1	Wenn Käfer und Feld nebeneinander sind, dann das blaue Feld anklicken, das unter Käfer oder Feld ist. Wenn nicht nebeneinander = Häuser in der Mitte, dann rechts klicken.
	Test day2	Erst nicht sicher. Dann eine Art Memory. Allerdings kam es mir so vor, dass bei gleichen Klicks es mal richtig und mal falsch war. Morgen kommt sicher noch ein 4. Kästchen und auch dann werde ich es nicht verstehen.
	Test day3	Ich habe keine Ahnung und sehe auch keinen Zusammenhang.
IGE24	Test day1	Die wechselnde Bilderreihenfolge danach zu bewerten ob man bei Anklicken eines gewissen Bildes Geld bekommt oder nicht. Besonders der Marienkäfer und die rechte Maustaste brachten Geld.
	Test day2	Ich glaube, dass es heute um die Bilderreihenfolge ging (bei d. Reihenfolge Wasser - Blumen - Käfer auf das rechte Feld drücken); heute war das Feld für den Käfer falsch.
	Test day3	Heute habe ich an keiner Stelle einen Zusammenhang erkannt.
MAS12	Test day1	Gedächtnisaufgabe; Reihenfolge der Bilder; bestimmte Darbietung erfordert die linke Taste; Rapsfeld (links) -> Rhein (Mitte) -> Marienkäfer (rechts); ansonsten nur rechts drücken.
	Test day2	Die Aufgabe war die gleiche von gestern, aber mit mehr Auswahl. Wenn Rapsfeld rechts oder in der Mitte erschien, dann reagiere ich rechts und wenn: Rapsfeld (links) -> Rhein (Mitte) -> Marienkäfer (rechts) -> mittlere Taste; wenn: Rapsfeld (links) -> Marienkäfer (Mitte) -> Rhein (rechts) -> linke Taste.
	Test day3	Es war dieselbe Aufgabe, aber mit noch mehr Kombination! Rapsfeld (rechts) -> Rhein (Mitte) -> Marienkäfer -> rechte Taste; Marienkäfer (links) -> Rapsfeld (Mitte) -> Rhein (rechts) -> 2. Taste rechts. Die anderen möglichen Kombinationen konnte ich nicht rausfinden.
AGN03	Test day1	Herauszufinden, wann und warum ein Smiley auftaucht. Aber hatte das Gefühl, dass rechts überzufällig häufig richtig war und deshalb habe ich am Ende durchgehend rechts gedrückt. Ich konnte leider keine Regel oder ein Prinzip feststellen, bei dem der Smiley aufgetaucht wäre.
	Test day2	Die Aufgabe war vermutlich dieselbe wie gestern, bis auf die zusätzliche dritte Taste, die gedrückt werden konnte. Ich habe versucht die rechte Taste zu drücken, wenn die Reihenfolge der Bausteine um eins nach rechts verschoben wurde, die linke Taste, wenn sie um eins nach links verschoben wurde und die mittlere Taste zu drücken, wenn die Reihenfolge der drei Bilder eine ganz andere war wie das Mal davor. Die Regel scheint sich aber nicht bestätigt zu haben.
	Test day3	Dieselbe wie die Tage davor, allerdings gab es jetzt 4 Tasten statt 3. Ich habe die linke Taste immer dann gedrückt, wenn die Reihenfolge vom Anfang gezeigt wurde und die ganz rechte, wenn diese Reihenfolge rückwärts gezeigt wurde. Wofür jedoch die mittleren Tasten sind, konnte ich nicht feststellen.

GCL30	Test day1	Immer nach den Bildern auf den rechten Button klicken, manchmal auch vorher noch mit der Maus auf den Marienkäfer klicken.
	Test day2	Manchmal war es richtig auf den Balken ganz rechts zu klicken, manchmal aber auch nicht.
	Test day3	Keine Ahnung, hab ich immer weniger verstanden von Tag zu Tag.
CNR16	Test day1	Bestimmte Reihenfolge einiger Bilder einem „Kasten“ zuordnen.
	Test day2	Bei der Bilderkombination Feld-Stadt-Käfer wurde es dem 2. Button zugeteilt. Bei K-S-F dem 1. Button, bei allen anderen Kombinationen dem 3. Button. Auch gab es zu bestimmten Reihenfolgen bestimmte Antwortmöglichkeiten.
	Test day3	Ebenso wie die Tage davor, allerdings gab es nun 4 Antwortmöglichkeiten.
UTC01	Test day1	6x rechts klicken; Reihenfolge der Bilder beachten.
	Test day2	Da wo Marienkäfer ist klicken (stimmt nicht immer); Zusammenhang: Reihenfolge beachten.
	Test day3	Zuerst wieder Marienkäfer beachtet (stimmte nicht); dann wenn Bilder nach links/rechts wanderten auch links/rechts klicken (stimmte auch nicht); Zusammenhang: Reihenfolge der Bilder.
ESB02	Test day1	Ich musste anhand der Bilderreihenfolge entscheiden, ob die rechte Taste oder die linke Taste gedrückt werden sollte.
	Test day2	Ich muss bei Stadt-Blumenwiese-Käfer auf den linken Balken klicken, bei Marienkäfer-Stadt-Blumenwiese auf den 2. von links und bei allen anderen Reihenfolgen rechts. (Die 3 Bilder am Anfang geben an, bei welcher Reihenfolge ich die linke Taste betätigen sollte, für die 2. von links war es die gleiche Reihenfolge, bloß verschoben. Heute wurde auf die gestrige Aufgabe aufgebaut, indem eine weitere Taste dazu kam, die bei einer Abwandlung der ersten Bilderreihenfolge einherging.
	Test day3	Bei Stadt-Marienkäfer-Blumen: linkes Rechteck (Reihenfolge wie sie am Anfang präsentiert wird); Bei Marienkäfer-Stadt-Blumen: 2. Rechteck von rechts; Bei Stadt-Blumen-Marienkäfer: 2. Rechteck von links; bei allen anderen: rechtes Rechteck. Es wird eine weitere Taste mit einer weiteren Reihenfolge gepaart. Hier wurde genau wie am Vortag einer Taste eine Reihenfolge zugeteilt, alle anderen möglichen gehörten auf die rechte Taste.
CRS25	Test day1	Ich glaube, dass die Aufgabe darin bestand, ein Muster zu erkennen. Die Bilder standen für mich in keinem direkten, logischen Zusammenhang.
	Test day2	Ich glaube, dass es bei diesem Experiment um Assoziationen und Wiedererkennung geht. Bis auf das Hinzufügen eines weiteren Antwortbuttons ist mir keine Änderung am Versuchsaufbau aufgefallen. Ich gehe also davon aus, dass sich die Aufgabe von gestern nicht verändert hat.
	Test day3	Ich glaube weiterhin, dass es um das Erkennen von Mustern geht. Da der Ablauf des Versuches nur geringfügig verändert wurde, gehe ich auch hier weiterhin davon aus, dass sich die Aufgabe nicht verändert hat und somit ist ein Zusammenhang erkennbar.

HJD02	Test day1	Herauszufinden, wann ich für meine richtige Antwort belohnt werde. Habe mich an dem Haus und der Seite orientiert. Wenn Haus in der Mitte und ich falsch lag, dann habe ich die Seite mit dem Marienkäfer genommen.
	Test day2	Wenn der Käfer links oder rechts war, die rechte Taste drücken (stand alleine). Am Anfang habe ich den Käfer ausgewählt und mich deshalb auf ihn konzentriert. Wenn Käfer in der Mitte gegebenenfalls die linke Taste (unsicher). Zusammenhang: Je nachdem was man am Anfang auswählt, ist die Aufgabe anders.
	Test day3	Wenn Käfer in der Mitte und Kornfeld links bzw. rechts, dann Mitte links bzw. Mitte rechts drücken. Sonst immer wenn der Käfer links oder rechts war, die ganz äußere rechte Taste drücken! Ausnahme: Wenn Käfer links und in der Mitte der See war, dann die linke (ganz außen) drücken.
PEH04	Test day1	Blumenwiese/Marienkäfer -> starke Assoziation -> bilden Bildpaar, zwei Kästchen zeigen an, was zusammengehört, wenn Kästchen bei Marienkäfer/Wiese eines von beiden wählen, wenn Kästchen auf Bild mit Fluss, auswählen um auszuschließen.
	Test day2	Zwei Kästchen eng nebeneinander zeigen Zusammengehörigkeit der Bildpaare an, das nicht dazugehörige Bild sollte ausgeschlossen werden (1. Kästchen). Ist Regel Assoziation der Bilder oder zeigen Bilder „Geschichte“? -> Käfer auf Wiese = :-), Käfer im Fluss = :-(.
	Test day3	Siehe Vortag.
CMN09	Test day1	Win-stay, lose-switch. Solange Geld zu gewinnen war, habe ich immer denselben Button gedrückt; wenn nicht, habe ich meine „Strategie“ geändert und den anderen Button gedrückt. Die Bilder waren meiner Meinung nach nicht aussagekräftig.
	Test day2	Die gleiche Aufgabe wie am Vortag.
	Test day3	Die gleiche Aufgabe wie am Vortag. Möglicherweise hatte es etwas mit der Position des Marienkäfers zutun.
IHH12	Test day1	Herauszufinden, wie die Aufgabe der Studie lautet; Eigenverantwortliches Denken zu fördern, vielleicht auch Neugierde
	Test day2	Die Aufgabe des Vortags schien der heutigen Aufgabe sehr ähnlich zu sein. Ich denke es hat etwas mit den Positionierungen zutun, wobei ich mir noch nicht sicher bin, warum das Bild mit dem Stadt/Fluss als negativ kommentiert wird, egal welche Positionierung es annimmt. Marienkäfer und Rapsfeld sind oft positiv. Ich vermute, die Aufgabe heute war unter anderem herauszufinden, ob es einen Zusammenhang mit der gestrigen Aufgabe gibt.
	Test day3	Ja, ich sehe eine Verknüpfung mit der Aufgabe des Vortags. Es erinnert mich etwas an ein Strategiespiel. Die Kästchen, die hinzukommen, haben mich etwas verwirrt, sodass ich mir unsicherer geworden bin, welches Kästchen ich klicken muss. Ich denke immer noch es hat etwas mit der Positionierung der Bildchen zutun, wann ich welches Kästchen anklicken muss.

DDH22	Test day1	Man sollte das Bild in der Mitte nennen, irgendwie?! (Maus ging nicht, hatte ein paar Mal versucht zu klicken...).
	Test day2	Man muss irgendwie klicken, wenn der Marienkäfer da ist, teils auf das räumlich gleiche blaue Kästchen, aber keine Ahnung nach welcher Regel.
	Test day3	Je nach dem in welcher Reihenfolge sich der Marienkäfer befand, musste man vieles klicken, aber Regel habe ich nicht erkannt.
KSD16	Test day1	Das Anfangsbild wiedererkennen, dann rechts ablehnen und links übereinstimmen, ob mit Anfangsbild identisch (bzw. Reihenfolge des zuerst gezeigten Bildes). „Raps-Käfer-Pisa“.
	Test day2	Bild von gestern wiedererkennen und auch neues Bild von heute, dafür die zwei linken Knöpfe. Wenn keins übereinstimmte, rechte Taste. „Felder-Pisa-Käfer.
	Test day3	Bild vom 1. Tag wiedererkennen -> 2. Taste von links; Bild vom 2. Tag wiedererkennen -> 3. Taste von links; neues Bild von heute -> 1. Taste von links; Ablehnen wenn unbekanntes Bild -> rechte Taste. (Bild heißt Reihenfolge/Anordnung der 3 Bilder). „Käfer-Pisa-Raps“.
MLB18	Test day1	Erst dachte ich, dass die Bilder egal sind (nach mehrmaligem Ausprobieren) und man 3x rechts und dann 1x links drücken muss. Das hat eine Weile geklappt, dann nicht mehr. am Ende dachte ich, dass ich immer rechts drücken muss außer der Raps ist rechts.
	Test day2	Man musste immer rechts drücken, manchmal war es falsch, aber ich konnte keine Regel erkennen. Wie gestern war meistens rechts richtig.
	Test day3	Ich dachte die Knöpfe stehen für die Position des Bildes steht bzw. ihre relative Bewegung. Das hat aber nicht gestimmt. Ich konnte auch nicht eine Reihenfolge der Knöpfe erkennen, die ich drücken sollte. Ich weiß die Regel nicht, glaube aber, dass es eine andere als gestern ist.
BCR29	Test day1	Die Positionen bestimmter Bilder bzw. Bildreihenfolgen anzugeben. Knopf rechts für eine bestimmte Kombination und Knopf links für eine andere.
	Test day2	Relationen der Bilder zueinander angeben. Ja, sehe ich (gleiche Aufgabenstellung); Knopf: siehe oben.
	Test day3	Knopf wieder für eine bestimmte Kombination der Bilder. Sollte rausfinden, welcher Knopf für welche Kombination.
NMK26	Test day1	Tier von Landschaft zu unterscheiden, besser gesagt das was nicht passt anklicken.
	Test day2	Ich denke, heute sollte ich ein paar Mal hintereinander auf das Tier klicken und dann nach gewissen Durchgängen fand ein Wechsel statt, wobei direkt nach einem Vorgang wieder das Tierbild relevant war.
	Test day3	Ich dachte, man muss 3x hintereinander Tier-Bild klicken, dann einmal Landschaft. 2. Tierbild fast immer wenn See-Bild rechts daneben ist und Tier immer wenn rechts/links.
IMF12	Test day1	Vermutlich hatte die Aufgabe etwas mit der Reihenfolge der Bilder zu tun.
	Test day2	Ich glaube, es hatte wieder etwas mit der Reihenfolge zu tun.
	Test day3	Ich glaube, es ging um das Bild in der Mitte.

HJS21	Test day1	Herauszufinden, wie das Spiel funktioniert, das man interagieren muss.
	Test day2	Dass die Versuchsleitung neben einem sitzt und bei Betätigung der richtigen Schaltfläche Geld in ein Schälchen wirft, war wie Konditionierung. Es gab eine Schaltfläche mehr und meistens war der Smiley hinter der gleichen versteckt.
	Test day3	Heute ist mir aufgefallen, dass sich die Fotos bewegt haben/die Reihen folge sich verändert hat, konnte den Wechsel der Bilder aber nicht in Zusammenhang mit den blauen Schaltflächen bringen.
MHV4	Test day1	Sich auf Grund einer Bilderanordnung zugrunde liegenden Musters für die rechte oder linke blaue Schaltfläche zu entscheiden.
	Test day2	Ich denke, man sollte aufgrund der Reihenfolge, in der die Bilder angeordnet waren, eines der drei Felder auswählen. Ähnlich wie gestern, aber die Chance richtig zu raten war natürlich geringer und somit schwerer, durch Ausprobieren einen Algorithmus zu finden.
	Test day3	Ich denke, dass die Bilder auf vier verschiedene Weisen angeordnet waren und dass jede der Anordnungen (vielleicht waren es auch mehr als 4) jeweils einer Schaltfläche zugeordnet waren, die man drücken musste. Ähnlich wie gestern, nur mit mehr Varianten. Vielleicht waren die Bilder aber auch total egal und es ging darum, die einzelnen Schaltflächen in einer bestimmten Reihenfolge anzuklicken.
EJM19	Test day1	Wenn der Marienkäfer mittig oder rechts zu sehen war, musste links geklickt werden. Wurde er links dargestellt schien es davon abzuhängen, in welcher Reihenfolge die beiden anderen Bilder rechts daneben positioniert waren.
	Test day2	Ich habe die Reihenfolge, die evtl. vorgegeben sein musste um eine bestimmte Taste zu drücken, nicht ermitteln können. Einen Zusammenhang zur vorherigen Aufgabe habe ich für mich nicht herstellen können, schließe ihn aber auch nicht aus.
	Test day3	War der Marienkäfer rechts, musste der Kasten unter dem Bildausschnitt mit dem Fluss angeklickt werden. War eigentlich ganz auf der anderen Seite, wurde der Kasten für das Feld angeklickt. Wurde der Marienkäfer mittig präsentiert, ist es mir nicht ganz klar.
MJP28	Test day1	Die blaue Flecke zeigen, welche 2 Bilder sollen sich zeigen, die links und rechts waren.
	Test day2	Bei Bildern, die ich gestern gesehen habe -> musste ich Mitte drücken. Bei Bildern, die habe ich heute wie gestern gesehen, musste ich links drücken und bei anderen Bildern musste ich rechts drücken.
	Test day3	Das Bild, das ich am ersten Tag als das erste sah, drückte ich 3. blauen Fleck von links. Das erste Bild von gestern drückte ich 2. Fleck von links. Das erste Bild von heute drückte ich 1. Fleck von links. Bei allen anderen Bildern drückte ich Fleck ganz rechts.

EJB07	Test day1	Ich muss die richtige Folge der Bilder finden und dann mit linker blauer Fläche zeigen.
	Test day2	Ich muss die richtige Folge der Bilder finden und dann mit linke blauer Fläche die neue Folge zeichnen und mit mittlerer Fläche die Folge von gestern.
	Test day3	Ich muss mit linker blauer Fläche die neue Folge zeigen dann gestern Folge mit zweiter Fläche und die Folge von Montag war dritte Fläche. 4. Fläche war für die anderen Kombinationen.
GWW17	Test day1	Meine Aufgabe war, die Positionen der Bilder zu merken und dementsprechend die blauen Kästchen anzuklicken. Bei einer bestimmten Reihenfolge der Bilder musste man das linke Kästchen anklicken, sonst immer rechts.
	Test day2	Aufgabe war immer linkes blaues Feld zu klicken, wenn rechts Stadt und in der Mitte der Maikäfer und links das Getreidefeld dargeboten wurde, mittleres blaues Feld, wenn Reihenfolge rechts Stadt, Mitte Getreidefeld und links Maikäfer dargeboten wurde, sonst immer rechts blaues Feld egal welche Reihenfolge. Zusammenhang: Die Reihenfolge der Bilder ist an beiden Tagen relevant! Also besteht ein Zusammenhang.
	Test day3	linkes blaues Feld, wenn Reihenfolge: von links: Getreidefeld, Stadt, Marienkäfer; von links 2. blaues Feld: immer wenn links Getreidefeld, Käfer und rechts Stadt; von links 3. blaues Feld: immer wenn links Käfer, dann Getreidefeld und rechts Stadt; Rechtes Feld immer wenn alle anderen Kombinationen. Zusammenhang: Ja, da die Reihenfolgen, die relevant waren, die gleichen waren, nur ein blaues Kästchen weiter und eine neue Reihenfolge wieder hinzukam.
SHD23	Test day1	Den gegenüberliegenden Button klicken, je nachdem ob rechts oder links der Marienkäfer zu sehen.
	Test day2	Je nach Anordnung der Bilder war ein Button der Richtige, leider konnte ich mir die richtige Reihenfolge nur schwer merken.
	Test day3	Leider weiß ich noch viel weniger als gestern.
BNR11	Test day1	Rechts zu klicken, wenn Marienkäfer und Stadt nebeneinander waren, wenn dies nicht der Fall war auf das linke Kästchen klicken.
	Test day2	Aufgabe: linkes Feld klicken, wenn von links nach rechts Stadt, Raps, Käfer; mittleres Feld klicken, wenn von links nach rechts Käfer, Raps, Stadt; ansonsten rechtes Feld klicken. Zusammenhang: Reihenfolge der Bilder bestimmt, welches Feld angeklickt werden soll.
	Test day3	Ja nach dem in welcher Reihenfolge die Bilder waren, musste ich auf eines der Felder klicken. Wahrscheinlich musste ich die Reihenfolge vom Anfang vergleichen. Zusammenhang: Reihenfolge der Bilder bestimmt, welches Feld angeklickt werden soll.

EIF26	Test day1	Bilder einprägen; Hat die Zeitlänge der Töne sich verändert; Bestimmte Abfrage der Bilder?
	Test day2	Schrille Töne vermeiden; Muster erkennen, wie sie zu vermeiden sind?
	Test day3	Eigentlich die gleiche Aufgabe wie am Vortag?
ABM23	Test day1	Demonstrieren, dass Geld und Smiley als Verstärker wirken; Einschätzen der Gewinnwahrscheinlichkeiten der blauen Boxen, Reaktivität zur Vermeidung aversiver Geräusche zeigen.
	Test day2	Siehe oben; Beantworten der Frage: Wie intuitiv übernimmt man die rechte Box für die höchste Wahrscheinlichkeit aus Teil 1 ohne empirische Überprüfung.
	Test day3	Unterschiede in Übergangswahrscheinlichkeiten zwischen Tagen; geänderte Gewinnwahrscheinlichkeiten von Buttons wahrnehmen.
KSD13	Test day1	Rechts zu klicken, wenn A nicht eintrifft mit A als die Reihenfolge von rechts nach links: Käfer, Blumen, Stadt.
	Test day2	Wenn er Käfer rechts oder in der Mitte ist, rechts klicken. Wenn der Käfer links ist und die Blumen in der Mitte, dann das mittlere Kästchen, wenn die Stadt in der Mitte ist, ganz links.
	Test day3	Wenn der Käfer rechts ist, den rechten Knopf drücken. Wenn der Käfer in der Mitte ist, mit den Blumen links dann auch. Mit Käfer links und der Stadt in der Mitte den linken mittleren Knopf drücken.
SJL21	Test day1	Reihenfolge der Bilder merken und den blauen Kästchen zuordnen.
	Test day2	Je nach Reihenfolge der Bilder musste ein bestimmtes Feld angeklickt werden. Heute waren 3 Felder, gestern nur zwei.
	Test day3	Erneut ist ein blaues Kästchen dazugekommen, allerdings weiß ich nicht, warum. Daher habe ich wieder die Reihenfolge der Bilder den Kästchen zugeordnet, das System war etwas anders.
BPD14	Test day1	Aufgabe zur Konditionierung, kreative Problemlösung, Problemlösen durch „trial and error".
	Test day2	Implizites Lernen, Aufgabe wurde um eine Antwortalternative erweitert. Frage: Wie kann neue Regel in gelerntes integriert werden? gibt es Konflikte?
	Test day3	Siehe Vortag.
PWM20	Test day1	Auf die rechte Taste drücken bei jeder Reihenfolge außer Käfer-Blume-Wasser -> dann linke Taste.
	Test day2	Ganz links drücken bei: Käfer-Wasser-Blume; halb links drücken bei: Käfer-Blume-Wasser; rechts drücken bei allen anderen Reihenfolgen.
	Test day3	Ganz links bei: Wasser-Blume-Käfer; Mitte links bei: Käfer-Wasser-Blume; Mitte rechts bei: Käfer-Blume-Wasser; ganz rechts bei allen anderen Reihenfolgen.

PMT11	Test day1	Auf die Reihenfolge/Anordnung der 3 Bilder achten: bei gleicher Reihenfolge das rechte Kästchen anklicken, bei geänderter Reihenfolge das linke Kästchen; eines der Bilder änderte seine Position -> links oder rechts klicken bei Nichtänderung/Änderung.
	Test day2	Auf die Reihenfolge der 3 Bilder achten; statt 2 blaue Kästchen gab es 3 Kästchen; das „Panoramabild“ war ausschlaggebend, bei Anordnung ganz rechts rechtes blaues Kästchen; ähnliche Abfolge der Bilder wie am Vortag.
	Test day3	Statt 3 blaue Kästchen gab es 4 Kästchen; 3 Bilder am Anfang einprägen und dann rechts blaues Kästchen klicken, wenn die gleiche Reihenfolge, sonst linkes blaues Kästchen.
AAD04	Test day1	Hypothese: immer das blaue Bild, dann dass immer die gleiche Abfolge von Bildern kommt und man sich merken muss wann rechts und wann links richtig ist.
	Test day2	Am Anfang wählt man ein Bild aus, dieses ist dann meistens richtig. Es kommt immer die gleiche Abfolge von Bildern, ab einer bestimmten Stelle ist das Bild mit dem Marienkäfer auf einmal nicht mehr richtig. Dann muss man irgendwie 1 raten und sich merken was stimmt?
	Test day3	Die Reihenfolge der Bilder am Anfang hat irgendwas zu bedeuten. Aber keine Ahnung warum es auf einmal 4 Kästchen gab und welches man drücken sollte, kam mir eher wie ein Ratespiel vor?! :D
MBA04	Test day1	Man drückt 6-mal rechts und 2-mal mal links, wenn man wieder hört.
	Test day2	Die Reihenfolge ist wichtig: 2 rechts, 1 links, 1 rechts, 1 mitte und Durchgang wiederholt sich bei dieser Reihenfolge.
	Test day3	Am Anfang an die Reihenfolge gedacht, aber die Reihenfolge wiederholt sich nicht und hab nix von Bildern verstanden (Bilder zu kurz präsentiert).
EVB02	Test day1	Auf die Anordnung der Bilder zu achten und bei einer bestimmten Reihenfolge zu klicken -> wenn die Bilder (der Reihe nach/einzeln) rechts erscheinen.
	Test day2	Klicken, wenn Stadt oder Rapsfeld rechts außen; Marienkäfer rechts außen, dann dort klicken wo Stadt ist; Gestern konnte man klicken, wenn auch Marienkäfer rechts außen war (glaube ich).
	Test day3	Klicken, immer wenn Rapsbild rechts, immer wenn Rapsbild links und Stadt rechts, dann bei Stadt klicken, wahrscheinlich wenn Marienkäfer rechts.

GAD12	Test day1	Zuerst (Bild mit Marienkäfer, Stadt, Feld) auswählen was zusammengehört; bei blauen Kästchen immer auf Positionen der Bilder vorher achten (immer wenn Marienkäfer neben Feld) -> rechtes Kästchen.
	Test day2	Auf Position der Stadt/Häuser achten -> stimmt allerdings nicht in allen Fällen! Immer noch: Immer wenn Feld neben Marienkäfer = rechtes Kästchen.
	Test day3	Bestimmte Reihenfolgen beachten z.B. bei Marienkäfer, Feld, Stadt rechts. Für jede Reihenfolge bestimmtes Kästchen zugeteilt, ähnlich wie an Vortagen.

Experiment 2

Responses on the verbal disclosure

AAN13	Test day1	Die 3 Bilder aufgrund von bestimmten Kriterien im Zusammenhang mit den 4 blauen Kästchen bringen.
	Test day2	Meiner Meinung nach war es die gleiche Aufgabe. Die Anordnung der Bilder hat Einfluss.
	Test day3	Die Aufgabe hat sich nicht verändert. Der Zusammenhang ist daher, dass sie gleich sind.
AEL03	Test day1	Illegible.
	Test day2	Wie gestern ging es um eine Bilderordnung zu den jeweiligen 4 Feldern. Die erste Reihenfolge der Bilder sollte man sich in jedem Falle merken.
	Test day3	Wiederholt gesagt die erste Reihenfolge auf dem Bildschirm merken, diese Reihenfolge ist immer richtig und zu den jeweiligen Feldern zuzuordnen. Und immer die erste Reihenfolge im Kopf behalten und sich an ihr orientieren und bei Variation der Reihenfolge durch die jeweiligen 4 Felder orientieren.
APE08	Test day1	Die Reihenfolge der Bilder. Im Anschluss habe ich mich an der Position des Marienkäfers orientiert. Einfach nur rechts klicken.
	Test day2	Gleiche Aufgabe, aber heute habe ich mich an den Positionen des Marienkäfers und der Stadt orientiert. Marienkäfer zur linken der Stadt: rechts. Marienkäfer zur Rechten der Stadt: links.
	Test day3	Abwandlungen der gestrigen und vorgestrigen Aufgabe. Orientierung an der Position des Marienkäfers. Nur beim ganz rechten Button kommt ein Smiley (Mittleren nie und links heute auch nicht). Reihenfolge der Bilder (groß)eine Rolle? (Marienkäfer – Blumenwiese – Stadt).
CHH12	Test day1	Die Tastatur reagiert nicht. Muster in der Reihenfolge konnte ich nicht erkennen. Es kann alles Mögliche sein.
	Test day2	Die Bilder starteten in einer anderen Reihenfolge. Mehr Unterschiede konnte ich nicht erkennen. Ob hinter der Reihenfolge eine mathematische Ordnung steckt, kann ich ohne Stift und Papier nicht erkennen.
	Test day3	Gleiche wie gestern.
CJM27	Test day1	Wie lange kann ich mich langweilen. Punkt ab dem ich irgendetwas unternehme!
	Test day2	(hoffentlich) Lerneffekt von gestern, d.h. Smiley finden.
	Test day3	Variation der Bilder Einfluss auf Stelle des Auftauchens der Smilies.

DAK21	Test day1	Die Position des Feldes durch Maus-Klicken lokalisieren
	Test day2	Die Aufgabe war, den linken Kasten anzuklicken, sobald die Bilder-Konstellation diejenige war, die zu Anfang gezeigt wurde. Der rechte Kasten wurde angeklickt, sobald diese Konstellation anders war. Allerdings stimmte der rechte Kasten bei einer bestimmten Konstellation auch wieder nicht. Die Aufgabe schien die gleiche wie am Vortag gewesen zu sein (ich hatte nur das Gefühl, mehr dahinter gekommen zu sein).
	Test day3	Aufgabe war grundsätzlich die Gleiche. Linke Taste: Gezeigte Reihenfolge (anders als gestern!). 2. Taste von Links: Reihenfolge von gestern. Rechte Taste: alle anderen Reihenfolgen. 3.Taste von Links hat keine Funktion Eine Taste ist hinzugekommen. Gestiegener Schwierigkeitsgrad.
DEG15	Test day1	Bestimmte Felder anklicken je nach Reihenfolge der gezeigten Items?
	Test day2	Ich konnte kein Muster bezüglich des Feldes, welches angeklickt werden sollten, erkennen (Auswahl?!?).
	Test day3	Erstes blaues Feld anklicken bei initial gezeigter Itemreihenfolge.
EBD01	Test day1	Einen der blauen Knöpfe auswählen (un-)abhängig von der Reihenfolge der gezeigten Bilder.
	Test day2	Nein, kein Zusammenhang zum Vortrag Zumindest keinen, der für mich sinnvoll aufeinander aufbaut. Die Aufgabe schien dieselbe zu sein wie gestern.
	Test day3	Nein, noch immer kein Zusammenhang erkennbar. Und leider auch kein Muster bezüglich der Icons und der Resonanz (Ton oder Smiley) erkennbar. Ansonsten kein Unterschied zu gestern und vorgestern.
EDR22	Test day1	Bildkonstellation bestimmten „Kästchen“ zuweisen.
	Test day2	Gleiche Aufgabe wie gestern (identische Bilder, gleiches System). Lösungsweg: immer wenn in Reihenfolge Marienkäfer außen; rechtestes Feld. Wenn zu Anfang eingeblendete Reihenfolge; linkes Feld. Wenn Marienkäfer mittig mit umgekehrter Bilderfolge außen; 2. Taste von links.
	Test day3	Gleiche Aufgabe wie die vorausgegangenen 2 Tage, heute andere Reihenfolge mit Vierecken verbunden.
EJG12	Test day1	Die Reihenfolge der Bilder beobachten. Einfach versucht
	Test day2	Es geht um die Reihenfolge der Bilder, wie sie zu Beginn gezeigt werden Wenn die Reihenfolge stimmt, muss der 2. Button von links gedrückt werden.
	Test day3	Wenn die gestrige Reihenfolge gezeigt wurde, musste der Button 2 von links gedrückt werden. Bei der Reihenfolge vom 3. Tag musste der ganz rechte Button gedrückt werden

ERD08	Test day1	Nach der Reihenfolge der Fotos musste ein bestimmtes blaues Feld gedrückt werden.
	Test day2	Die gleiche wie gestern!? Obwohl bei den meisten Bilderkonstellationen auf den gleichen blauen Kasten zu drücken war und bei den 2 bestimmten Konstellationen der blaue Kasten nicht richtig war, sondern ein anderer.
	Test day3	Diese heutige Aufgabe ähnelte mehr der ersten Aufgabe. Wieder war vermehrt der ganz echte blaue Kasten zu drücken bei der gezeigten Bilderkonstellation zu Anfang. Bei anderen Konstellationen waren aber im Vergleich zur zweiten Aufgabe vermehrt andere blaue Kästen anzuklicken.
ERW03	Test day1	Möglichst viele Smilies zu finden.
	Test day2	Das Gleiche wie am Vortag. Den Rhythmus von Smiley und Nicht-Smiley herausfinden.
	Test day3	Testen der Frustrationstoleranz in Verbindung mit Geschwindigkeit der Antworten nach Smiley oder Ton.
EWT01	Test day1	Die Reihenfolge der Bilder mit den Tasten zu verknüpfen.
	Test day2	Linke Taste: richtige Reihenfolge (wie die Bilder am Anfang präsentiert wurden). Rechte Taste: falsche Reihenfolge. 2. Taste von links: eine bestimmte Reihenfolge (Käfer, Fluss, Feld). Wichtig: neue Taste (die 2. Von links) wurde heute mitbenutzt. Schwierigkeitsgrad gestiegen: von 2 auf 3 Tasten.
	Test day3	Die Aufgabe ist gleich geblieben. Man muss verschiedene Reihenfolgen der Bilder mit den 4 Tasten verknüpfen. Die Linke Taste gehörte zu der anfänglich gezeigten Reihenfolge. Die zweite von Links hatte eine bestimmte Reihenfolge und zwar Feld, Käffer, Fluss; bei der dritten war es Käfer, Fluss, Feld. Die rechte Taste war für alle anderen Reihenfolgen, die auf die vorherigen Tasten nicht zutrafen. Der Schwierigkeitsgrad der Aufgabe ist mit jedem Tag gestiegen, da heute die vierte Taste dazu kam.
SNF24	Test day1	Vielleicht die gleichmäßige Veränderung der gezeigten Bilder, damit meine ich, dass eine bestimmte Reihenfolge eingehalten werden musste um ein Smiley zu bekommen.
	Test day2	Orientierung an der Position des Käfers. Assoziation/Zuordnung der Käfer-Position zu den Knöpfen. Versuch der Orientierung der anderen Bilder zu den Knöpfen.
	Test day3	Versuch des Erkennens der richtigen Reihenfolge der gezeigten Bilder, um den Smiley zu bekommen! Baut aufeinander auf!
RPK29	Test day1	Beobachtung: Veränderung der Reihenfolge der Bilder. Veränderung der Bilder?
	Test day2	Schaltfläche bedienen: in Abhängigkeit von der Bilderreihenfolge. Rechter Knopf öfter gedrückt (Marienkäfer wichtig?).
	Test day3	Schaltfläche bedienen in Abhängigkeit der Bilderreihenfolge. V.a. rechter Button und 2. Von rechts. Entscheidend Marienkäfer & Rapsfeld (Verhältnis zueinander?). Wenn Käfer links: nicht rechts drücken? Wenn Raps vorne: 2. Von rechts??

GOW14	Test day1	Beim Klicken auf das äußere der vier blauen Kästchen erschien oft mehrmals hintereinander ein Smiley, ich habe aber leider keine Ahnung, warum. Sah für mich ziemlich willkürlich aus.
	Test day2	Am Anfang dachte ich, dass es um die Bilderreihenfolge gehen würde (Die Vermutung hatte ich gestern auch, konnte sie allerdings nicht bestätigen). Ich habe begonnen, immer das rechts äußere, blaue Kästchen anzuklicken, wenn die Reihenfolge „Häuser – Rapsfeld – Marienkäfer" war. Waren die Häuser rechts, habe ich das linke äußere blaue Kästchen angeklickt, da daraufhin der Smiley erschien. Nach einigen Fehlversuchen habe ich die ‚Reihenfolge-und-relative-Position-des-Häuserfoto'-Theorie wieder verworfen und nur noch nach dem Zufallsprinzip ausprobiert. Dabei war der Klick auf die rechte äußere blaue Taste überzufällig oft richtig. Ich habe allerdings nach wie vor keine Ahnung, was die eigentliche Aufgabe ist.
	Test day3	Ich habe keine Ahnung. Habe es noch ein letztes Mal mit der Reihenfolgen-Strategie versucht und bin dann zwischenzeitlich zu dem Schluss gekommen, dass es eigentlich gar keine Aufgabe gibt, sondern die Smilies nur auf Zufallsniveau vergeben werden. Allerdings schließe ich aus einigen Kommentaren, das es wohl doch eine Aufgabe gab, die ich mit den mir verfügbaren geistigen Mitteln leider nicht erfassen konnte. Jedenfalls beschränkte sich meine heutige ‚Strategie' auf mehr oder weniger abwechselndes links äußeres Kästchen und rechts äußeres Kästchen anklicken (bei den beiden mittleren gab es nie ein ‚Siley-Feedback').
HAE15	Test day1	Anzugeben, ob die Reihenfolge der Bilder der am Anfang entspricht (Taste links) oder nicht (Taste rechts)
	Test day2	Eine andere… Leider ist mir der Regelunterschied nicht klar geworden. Manche Fälle der „nicht-Standard-Reihenfolge" funktionierten nicht mit Taste rechts, aber welche?
	Test day3	Keine Ahnung. Richtige Reihenfolge nach wie vor Taste links. aber sonst??
HVB23	Test day1	Erst dachte ich, es gäbe bestimmte Reihenfolgen, bei denen die rechte Karte nicht richtig ist, sondern die linke. Mindestens 2 sind also falsch, auch habe ich versucht abzuzählen.
	Test day2	Meine Annahme mit den 2 Reihenfolgen mit unterschiedlichen „Karten" hat sich bestätigt. Bei der Reihenfolge Käfer, Feld, Fluss (oder so ähnlich), musste die Karte ganz links ausgewählt werden. Bei Fluss, Feld, Käfer die zweite von links. Wenn ich mich recht erinnere, ist das jeweils die Reihenfolge und die umgekehrte Reihenfolge von den Bildern, die ganz am Anfang gezeigt wurden, die Reihenfolge gestern war glaube ich anders.
	Test day3	Auch hier musste anscheinend auf die Reihenfolge geachtet werden, jedoch kamen 1 oder 2 weitere abweichende hinzu. Die Reihenfolge Käfer, Fluss, Feld musste ganz links beantwortet werden. Käfer, Feld, Fluss mit der zweiten von links und eine umgekehrte Reihenfolge mit der zweiten von rechts.

HVV22	Test day1	Eine bestimmte Reihenfolge merken/bestimmen. Aber in diesem (…?) bin ich mir noch nicht sicher.
	Test day2	Ich sollte auf die 2. Blaue Kiste (Quadrat) drücken, wenn das gelbe ‚Senffeld' in der Mitte war und die Marienkäfer rechts von ihm. Bei allen anderen Kombinationen habe ich auf den 4. Quadrat (von links) geklickt.
	Test day3	Bei den Kombinationen: 1.Wasser 2. Marienkäfer 3.Feld; 1.Marienkäfer 2. Wasser 3.Feld; 1. Wasser 2. Feld 3.Marienkäfer klickte ich an dasjenige blaue Feld/Position, in dem Marienkäfer abgebildet wurde/also das die Position des Marienkäfers repräsentierte. Bei allen anderen Kombinationen klickte ich an das 4. Feld (von links)
IJL19	Test day1	Herausfinden, welche Bilderkombination bei welchem Knopf zum Smiley führt. Darüber nachgedacht, wie viele Kombinations-Möglichkeiten es gibt, passend zu 4 Knöpfen? Stadt Rechts und Stadt Mitte passt zu rechtem Knopf. Stadt Links und Marienkäfer Mitte passt zu linkem Knopf. Mittlere beide Knöpfe gingen (so gut wie) nie.
	Test day2	Ich glaube es war dieselbe Aufgabe wie gestern, denn die Kombination, die gestern zum Smiley führte, war auch heute richtig. Ich denke auch morgen kommt dieselbe Aufgabe und es geht um die Entwicklung/Verbesserung der Strategie über Tage?!
	Test day3	Gemeinsamkeiten: Kombi: Marienkäfer – Wiese – Stadt und Wiese – Marienkäfer – Stadt = rechter Button. Kombi: Marienkäfer – Stadt – Wiese = 2. Button von links. Kombi: Stadt – Marienkäfer – Wiese = 1. Button von links. Unterschiede habe ich keine bemerkt. Nur Gemeinsamkeiten. Ich denke auch, dass es dieselbe Aufgabe ist.
KSI14	Test day1	Die Reihenfolge der Bilder zu merken. Links klicken: richtige Reihenfolge. Rechts klicken. Die Bilder waren nicht nach Reihenfolge zugezeigt.
	Test day2	Die Reihenfolge der Bilder von heute zu merken und dabei an die gestrigen Bilder(/Reihenfolge) erinnern. Die Reihenfolge von heute: 1. Taste von links anklicken. Falsche Reihenfolge: 1. Taste von rechts.
	Test day3	Man sollte wieder eine neue Reihenfolge von Bildern merken. Dieselben Bilder, aber die Tasten (Rechtecke) musste man anders anklicken. 1. Taste: die heutige Reihenfolge. 2. Taste: die Reihenfolge vom 2. Tag. 3. Taste: Die Reihenfolge von 1. Tag. 4. Taste: Keine der 3 Reihenfolgen.
LJT22	Test day1	Herausfinden, wann (bei welcher Konfiguration [Hafen, Raps, Käfer]) links zu klicken. Generell ganz rechts klicken.
	Test day2	Reihenfolgen Käfer-Hafen-Raps ganz links klicken. Wenn Käfer in der Mitte: ganz rechts klicken. Reihenfolge der Bilder bestimmt zu klickenden Button.
	Test day3	Reihenfolge Hafen-Käfer-Raps: links klicken. Reihenfolge Käfer – Hafen – Raps: rechts klicken. Reihenfolge der Bilder bestimmt zu klickenden Button.
LRA09	Test day1	Bei einer bestimmten Bilderreihenfolge das letzte Feld rechts zu drücken.
	Test day2	Keine Ahnung, gleiche Aufgabe wie gestern.
	Test day3	Drei Bilder und vier Knöpfe. Die Bilder verändern ihre Reihenfolge was im Zusammenhang mit den Knöpfen steht.

MAC15	Test day1	Auf bestimmte Bilderreihenfolge mit bestimmten Button reagieren. Smiley bedeutet, richtige Antwort, „Tröte“ falsche. Der 4. Knopf stand für die meisten Reihenfolgen, die anderen weiß ich nicht.
	Test day2	Ich denke, dass es diesmal eine ähnliche Aufgabe war. Ich habe vermutet, dass es was mit der Reihenfolge der Bilder zu tun hat, welche wie vertauscht sind usw. War es ‚richtig‘, also 2 Bilder vertauscht, dann sollte ich den Button ganz rechts klicken, ansonsten ganz links. Leider ging es aber nicht ganz auf.
	Test day3	wieder die gleichen Bilder, ich ihrer Sequenz variierend. Wieder scheint der Button ganz rechts meistens die richtige Antwort inne zu haben. Wieder scheint der Button ganz links das Gegenstück zum Button rechts darzustellen. der 4. Button war nicht mehr so oft die richtige Lösung Die 1. Sequenz der Bilder unterschied sich, dementsprechend veränderte sich vermutlich die Lösung. Button 2 + 3 scheinen immer falsch zu sein.
MHB15	Test day1	Merken von Bilderfolgen mit Unterscheidung von 1.gezeigter zu weiteren Kombinationen.
	Test day2	Merken einer Bilderreihenfolge aus gleichen Bildern. 1. Taste: heutige Reihenfolge. 2. Taste: Reihenfolge von Vortag. 3. Taste: n/A. 4. Taste: andere Reihenfolge.
	Test day3	1. Taste: heutige Reihenfolge. 2. Taste: Reihenfolge von Vortag. 3. Taste: Vorvortag. 4. Taste: andere Reihenfolge.
PHK24	Test day1	Ist die Reihenfolge der drei Bilder richtig oder falsch? Bei einer richtigen Reihenfolge linkes blaues Feld, bei einer falschen Reihenfolge rechtes blaues Feld anklicken. Die beiden mittleren nicht beachten.
	Test day2	Der Unterschied bestand darin, dass ich heute das 2.blaue Feld anklicken musste, wenn die Reihenfolge der Bilder genau verkehrt herum (Das 1. Bild zuletzt und das letzte Bild als erstes) war, und nicht mehr das rechte Feld. Letzteres sollte also bei falscher Reihenfolge (aber nicht bei dem beschriebenen Sonderfall) und das linke Fed bei richtiger Reihenfolge angeklickt werden. Das dritte sollte wieder nicht beachtet werden.
	Test day3	Die heutige Aufgabe hatte mit den vorangegangenen gemeinsam, dass ich das linke blaue Feld bei richtiger und das rechte blaue Feld bei falscher Reihenfolge anklicken musste. Heute gab es allerdings einen (bzw. zwei) neue(n) Sonderfall(/Sonderfälle): Das erste Bild in der Mitte, das zweite Bild rechts und das dritte Bild links, dann musste das zweite blaue Feld angeklickt werden. Das erste Bild in der Mitte, das zweite Bild links und das dritte rechts, da hab ich die richtige Lösung nicht raus bekommen.
RAA08	Test day1	Merken wie oft die Bilder in welcher Reihenfolge gezeigt wurden.
	Test day2	Eventuell die Reihenfolge der anfangs gezeigten Einzelbilder merken. (War anders)
	Test day3	Die Reihenfolge der ersten 3 Bilder (von jedem Tag) merken. Eventuell den genauen Inhalt merken (vielleicht sollen am Ende sehr ähnliche Bilder unterschieden werden). Die folgenden Kombinationen der Bilder könnten zur Verwirrung dienen, damit die erste Abfolge schwerer zu behalten ist. Die Abfolge der übrigen Bildschirme + Töne könnte auch zu merken sein.

SED02	Test day1	In einem der Kasten könnte stehen, was auf dem ersten Bild drauf war.
	Test day2	In den Kasten steht nicht nur Beschreibung zum ersten Bild, es könnte Reihenfolge genannt werden (Bsp.: Käfer – Rapsöl – Fluss).
	Test day3	Für einige Bilder war richtig das vierte Viereck, für andere das zweite Viereck, das war gleich. Mir sind keine Unterschiede aufgefallen.
SKD07	Test day1	Ich sollte die Reihenfolge der Bilder merken und eins von den 4 blauen Feldern jeweils nach jeder Runde anklicken.
	Test day2	Ich sollte erkennen, ob die Bilder in der vorgegebenen Reihenfolge gezeigt wurden. Gestern erschien beim Drücken der 4 Felder beim blauen Feld auch ein Smiley bei richtiger Antwort und beim blauen Feld rechts bei falscher Reihenfolge. Diesmal war bei Feld rechts und bei Feld links ein Smiley.
	Test day3	Wenn alle Bilder in der Reihenfolge übereinstimmen und ich das linke blaue Feld drücke, erscheint der Smiley. Wenn eins der Bilder stimmte und ich rechts drückte, erschien der Smiley. Die Reihenfolge der Bilder war in jeder Sitzung anders. Eventuell sollte ich die Bilderreihenfolge von Montag/Dienstag mitberücksichtigen.
SNK30	Test day1	Ich denke dass ich auf die Reihenfolge/Zusammensetzung der Bilder achten musste und dann das dazugehörige Kästchen drücken musste. Allerdings traf dies nicht immer zu.
	Test day2	Ich denke, dass ich heute entscheiden musste, ob die anfangs gezeigte Reihenfolge eingehalten wurde (Stadt – Marienkäfer – Raps). Traf die Reihenfolge zu, habe ich den linken, äußersten Kasten gedrückt, war die Reihenfolge anders, den rechten äußersten Kasten. Ob dies gestern auch so war, weiß ich nicht so genau, da ich gestern eher geraten habe. Da heute die meisten Reihenfolgen nicht mit der Anfangsreihenfolge übereinstimmten, habe ich sehr oft den rechten, äußersten Kasten gedrückt und fast immer ein Smiley gezeigt bekommen. Allerdings traf meine Strategie nicht immer zu, was mich verwundert, jedoch weiß ich nicht so genau was daran falsch ist. Ich würde schätzen, dass in bestimmten Abständen meine Strategie nicht zutrifft, um mich zu verunsichern, aber das ist nur geraten.
	Test day3	Heute bin ich zunächst nach der gleichen Strategie vorgegangen, jedoch habe ich schnell gemerkt, dass dies nicht funktionierte. Was jedoch mit gestern übereinstimmte, war die Tatsache, dass ich den linken, äußersten Kasten drücken musste, wenn die gezeigte Reihenfolge mit der Anfangsreihenfolge (Stadt-Raps-Marienkäfer) übereinstimmte. Wenn dies allerdings nicht zutraf, versuchte ich mehrere Strategien, doch letztendlich habe ich nur geraten, da mir keine sinnvolle Strategie einfiel. Meistens habe ich den rechten, äußersten Kasten gedrückt, jedoch war dies oft falsch.

Experiment 3

Responses on the verbal disclosure

Group1

WWW24	Test day1	Reihenfolge mit Tasten verbinden.
	Test day2	Gleiche Aufgabe mit zusätzlicher Taste.
	Test day3	Gleiche Aufgabe mit 4 Tasten.
SHS19	Test day1	Die abweichende Kombination identifizieren und diese anhand des linken/rechten Entscheidungsknöpfe aussortieren.
	Test day2	Wie Tag 1, jedoch 1. abweichende Kombination als 1. Bild gezeigt. Zusätzlich 2. abweichende Kombination auf 2. Entscheidungsknopf, wobei beide Knöpfe f.d. Kombination rechts positioniert waren. 1. Kombi = rechts außen, 2.K = rechts innen.
	Test day3	Wie Tag zwei, jedoch zusätzlich 3. abweichende Kombination; Aufteilung: 1-2-3-4; 1 = richtige Kombi; 2,3 = abweichende Kombi; 4 = abweichende gelernte Kombi.
RJL01	Test day1	2 Systeme in der Reihenfolge der Bilder zu erkennen um dieses mit den beiden Feldern zuzuordnen.
	Test day2	Es gibt keine Aufgabe. Ich denke hier läuft nur ein Zufallsgenerator. Ich habe versucht Kombinationen in Abfolgen der Bilder, ihrer Bedeutung, Gestaltung, Inhalt, etc. Mit einem Knopf zu verbinden, stieß aber bei allen Möglichkeiten auf Wiedersprüche.
	Test day3	Die Reihenfolge der Bilder einem Button zuzuordnen.
RAH18	Test day1	Die Reihenfolge der Bilder wiederzuerkennen, also die Reihenfolge welche als erstes präsentiert wurde.
	Test day2	Die Reihenfolge vom ersten Durchgang wiedererkennen, diese ganz rechts angeben, sowie die Reihenfolge der Bilder vom letzten Mal erkennen und in der Mitte anklicken.
	Test day3	Die Aufgabe war es den neuen Durchgang zu erkennen und ganz rechts anzugeben und die andern beiden Durchgänge jeweils wieder zu erinnern und auf unterschiedlichen Kästchen anzuklicken.

NDM06	Test day1	Die Reihenfolge der Bilder zu überprüfen, ob diese richtig oder falsch war. Bei der Wiedergabe der Bilder in der aller ersten Konstellation und dem drücken des rechten Knopfes kam der Smiley, ansonsten beim linken, bei ungleichen Reihenfolgen.
	Test day2	Heute wurden die Bilder in umgekehrter Reihenfolge abgefragt, wenn die Bilder richtig warenmusste der ganz rechte Knopf gedrückt werden. Bei der Reihenfolge vom ersten Tag der neue Knopf. Bei einer falschen Folge der linke.
	Test day3	Heute wurden drei Muster abgefragt, ein neues mit dem ganz rechten Knopf, das vom zweiten Tag mit dem zweiten Knopf von rechts und das vom ersten Tag mit dem neuen Knopf. Der Knopf ganz links war wieder für eine falsche Reihenfolge.
MPB25	Test day1	Reihenfolge der Bilder merken; Reihenfolge war: Feld Stadt Marienkäfer. Wo man einsteigt, ob bei Stadt oder Marienkäfer, ist egal, Hauptsache die Reihenfolge wird beachtet.
	Test day2	Bestimmte Reihenfolge den drei Tasten zuordnen; Stadt Marienkäfer Feld z.B immer der 1. Taste.
	Test day3	linkes/erstes Kästchen: Feld Stadt Marienkäfer; rechtes/viertes Kästchen: Stadt Feld Marienkäfer; zweites/drittes Kästchen: raten?
MBT08:	Test day1	Je nachdem in welcher Position die Bilder auftauchen links oder rechts klicken. Dabei ändert sich das Ziel-Bild.
	Test day2	Kombination/Reihenfolge der Präsentation hat bestimmt welche der 3 Knöpfe es zu drücken gilt.
	Test day3	Jede der vier Felder stand für eine gewisse Anzahl an Kombinationen – das 1. Z.B. für 3 die anderen jeweils für eine weitere.
IMA14	Test day1	Drücke den linken Knopf; Ausnahme bei „Marienkäfer-Rhein-Raps“ drücke den rechten Knopf.
	Test day2	Drücke den linken Knopf; Ausnahme 1: Wenn „Marienkäfer-Rhein-Raps“ erscheint drücke den Knopf in der Mitte; Ausnahme 2: Wenn „Marienkäfer-Raps-Rhein“ erscheint drücke den rechten Knopf.
	Test day3	Drücke den linken Knopf; Ausnahme 1: Wenn „Rot-Blau-Gelb“ dann drücke den 2. Knopf von links; Ausnahme 2: Wenn „Rot-Gelb-Blau“ dann drücke den 3. Knopf von links; Ausnahme 3: Wenn „Gelb- Rot-Blau“ dann drücke den rechten Knopf.

HBH08	Test day1	Meine Aufgabe war es, eine Reihenfolge in den gezeigten Bildern zu erkennen und bei der Reihenfolge Stadt-Käfer-Feld rechts zu klicken und bei allen anderen links.
	Test day2	Meine Aufgabe war es bei der Reihenfolge Feld-Stadt-Käfer ganz rechts zu drücken, bei Stadt-Käfer-Feld in der Mitte (rechts) und bei allen anderen Kombinationen links.
	Test day3	Bei der Reihenfolge Stadt-Feld-Käfer ganz rechts drücken, bei Feld-Stadt-Käfer rechts-mittig, bei Stadt-Käfer-Feld links-mittig und bei allen anderen Kombinationen links.
GJK27	Test day1	Die Reihenfolge der Bilder herauszubekommen, die mir die meisten 5 Cent Münzen einbringt.
	Test day2	Die Bilder, die eine Belohnung, für das richtige Anklicken merken um möglichst viele 5 Cent Münzen zu bekommen.
	Test day3	Bilderreihenfolgen den richtigen Knöpfen zuordnen um den Smiley und damit 5 Cent zu bekommen.
DVO27	Test day1	4/5 x links klicken danach rechts, Reihenfolge der Bilder, wenn Anfangsreihenfolge – links.
	Test day2	links klicken bei falscher Reihenfolge oder Blumenwiese zu Beginn & richtiger Reihenfolge; Mitte: Gebäude + richtige Reihenfolge; rechts-Klick: Marienkäfer + richtige Reihenfolge.
	Test day3	Marienkäfer vorne + richtige Reihenfolge -> ganz rechts; Marienkäfer vorne + falsche Reihenfolge -> 3. von links; -richtige Reihenfolge + Feld oder Gebäude vorne oder Feld + falsche Reihenfolge -> 1. Feld ganz links; Gebäude vorne + falsche Reihenfolge -> 2. von links.
DTP17	Test day1	Bei Reihenfolge Häuser-Sonnenblumenfeld-Marienkäfer rechter blauer Knopf, sonst linker blauer Knopf. Bei richtiger Entscheidung 5ct, sonst nichts.
	Test day2	Bei der Reihenfolge Häuser-Rapsfeld-Käfer zweiter Knopf von rechts, bei der Reihenfolge Marienkäfer-Rapsfeld-Häuser ganz rechter Knopf – sonst den ganz linken- die Lösung für den rechten Knopf gestern ist quasi eins nach links gemacht um einer neuen Reihenfolge Platz zu machen.
	Test day3	Die Lösungen von gestern und vorgestern sind wieder einen Knopf nach links gerutscht und haben der Reihenfolge Marienkäfer-Häuser-Rapsfeld auf dem ganz rechten Knopf Platz gemacht. Diese Folge wurde ganz am Anfang präsentiert (Wahrscheinlich wurde das auch die anderen Male gemacht…).
BHF20	Test day1	Belohnungslernen durch try and error.
	Test day2	Reihenfolge der Bilder merken und die jeweilige Reihenfolge mit der entsprechenden Taste kombinieren.

	Test day3	Test day3: bereits gelernte Reihenfolge abrufen und richtig in einem neuem Setting kombinieren und mit neuer Bilderfolge ergänzen.

Group2

RRV16	Test day1	Marienkäfer, Häuser, Blumenwiese rechts drücken, ansonsten links.
	Test day2	Anfangssequenz sagt an, welche Reihenfolge rechts dazu kommt, die vom Vortag ist direkt links daneben, alle anderen ganz links.
	Test day3	Siehe Tag 2.
SCL10	Test day1	Die eine Reihenfolge der drei Bilder herauszufinden, bei der das rechte blaue Kästchen gedrückt werden muss.
	Test day2	Jeder Abfolge ein Kästchen zuordnen. Hat aber nicht funktioniert. Das erste Kästchen war später bei mehreren Kombinationen richtig.
	Test day3	Ich habe keine Ahnung – Evtl. immer das erste Kästchen nehmen, auch wenn kein Smiley kommt, da dies noch am häufigsten richtig war.
YJT05:	Test day1	Rechts oder links klicken abhängig von der Reihenfolge der Fotos. Wenn das Foto von Blumen am Ende kommt, hab ich links geklickt. Wenn das Foto von Gebäuden am Ende Kommt, hab ich rechts geklickt.
	Test day2	Rechts, Mitte oder links klicken. Es scheint, dass die Reihenfolge der Fotos nicht relevant ist. Es gibt immer bestimmte Zeit, wo ich immer richtig klicke und falsch klicke.
	Test day3	Ich habe gar keinen Zusammenhang zwischen der Reihenfolge der Fotos und der Richtigkeit (wo ich klicken soll) gefunden. Besonders heute habe ich relativ wenig richtig geklickt im Vergleich mit den anderen Tagen.
OVR03	Test day1	Regel rausgefunden -> Haus, Marienkäfer, Wiese -> drück rechts.
	Test day2	Haus, Wiese, Marienkäfer -> drücke rechts; Haus, Marienkäfer, Wiese -> drücke die linke Taste.
	Test day3	Haus, Marienkäfer, Wiese -> Taste 2; Haus, Wiese, Marienkäfer -> Taste 3; Wiese, Käfer, Haus -> Taste 4; Alles andere -> Taste 1.
MWM03	Test day1	Bei Kombination Stadt-Feld-Käfer -> rechts; Bei allen anderen Bildkombinationen -> links.
	Test day2	Kombination Stadt-Feld-Käfer -> Mitte; Kombination Käfer-Stadt-Feld -> rechts; sonst -> links
	Test day3	Kombination Stadt-Feld-Käfer -> Button 2; Kombination Käfer-Stadt-Feld -> Button 3; Kombination Stadt-Käfer-Feld-> Button 4; Sonst -> Button1
MPN16	Test day1	Festzustellen, ob es die gleiche Reigenfolge war, wie bei den ersten Bildern.
	Test day2	In der Mitte zu drücken, wenn die Abfolge von gestern war und rechts wenn die heutige erste Reihenfolge dran kam.
	Test day3	Rechts zu klicken, wenn die heutige Abfolge kam, links daneben, wenn die von gestern und auf die zweite Taste von links wenn die Bildabfolge von vorgestern kam.

MDI10	Test day1	„Häuser, Marienkäfer, Blumen“ als einziges rechts drücken / sonst links; blaue Felder evtl. als „ja“ / „nein“.
	Test day2	Linkes blaues Feld = „Regel“; rechte zwei Felder „Ausnahme“; linkes davon -> Reihenfolge „Häuser, Marienkäfer, Rapsfeld“; rechtes davon -> „Häuser, Rapsfeld, Marienkäfer“.
	Test day3	Blaues Feld = „Regel“; 2. Blaues Feld = Reihenfolge „Häuser-Marienkäfer-Raps“; 3. blaues Feld = Reihenfolge „Häuser-Raps-Marienkäfer“; 4. blaues Feld = Reihenfolge „ Marienkäfer-Raps-Häuser“.
LRH05	Test day1	Die Bilder wurden anhand einer bestimmten Reihenfolge gezeigt, die richtig oder abweichend zu davor war. Zudem änderte sich die Zuordnung von Ja und Nein zwischen den blauen Tasten. Es gab aber auch Durchgänge, in denen nur eine Taste gedrückt werden musste.
	Test day2	Die Reihenfolge von Gestern wurde wiederholt. Die Zuordnung war diesmal gleich zu gestern, falsch bekannt, falsch unbekannt.
	Test day3	Reihenfolge am Anfang vorgegeben. Dann Reihenfolge gleich ganz rechts, wenn falsch = ganz links; wenn verrückt = 2. von rechts, sonst 2. von links.
DWM18	Test day1	Eine Reihenfolge der Abspielung der Bilder zu suchen/finden obwohl es keine gab.
	Test day2	Die gleiche wie oben, nur dass ein Antwortbutton mehr vorhanden war, der den Eindruck erweckt, dass man mehr Fehltreffer als Treffer hat.
	Test day3	Die gleiche wie vorher, nur dass die Frustrationsgenze mehr ausgetestet wurde.
BRD26	Test day1	Seitenwahl nach Sympathie, Bilder eigentlich keine größere Bedeutung.
	Test day2	Auswahl nach Bilderpräferenz mit drei Wahlmöglichkeiten unabhängig von den drei gezeigten Motiven.
	Test day3	Kurz präsentierte Reize/Bilder zwischen den drei präsentierten Items, die zu einer Auswahlpräferenz führen sollten.
BMD09	Test day1	Bei der Reihenfolge „Stadt-Käfer-Feld“ auf das rechte blaue Kästchen, ansonsten auf das linke zu klicken.
	Test day2	Bei der Reihenfolge „ Stadt-Käfer-Feld“ auf das mittlere Feld, bei „Käfer-Stadt-Feld“ auf das rechte Feld und ansonsten auf das linke Feld zu klicken.
	Test day3	Bei der Reihenfolge „Stadt, Käfer, Feld“ auf das 2. Feld von links zu klicken bei „Käfer, Stadt, Feld“ auf das 2. von rechts, bei „Stadt, Feld, Käfer“ auf das rechte Feld zu klicken und ansonsten auf das linke Feld.

Eidesstattliche Versicherung

Ich versichere an Eides Statt, dass die Dissertation mit dem Titel:

Uninstructed Assessment of Episodic-like Memory in Humans.
With Especial Reference to Temporal Order

von mir selbständig und ohne unzulässige fremde Hilfe unter Beachtung der „Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf“ erstellt worden ist.

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