Markus A. Maier,[1] Vanessa L. Büchner,[1]
Christof Kuhbandner,[1] Markus Pflitsch,[1]
Maria Fernández-Capo[2] and
Maria Gámiz-Sanfeliu[2]

Feeling the Future Again

Retroactive Avoidance of Negative Stimuli

Abstract: *During the past decades, several theories have been proposed that relate quantum mechanics to information processing in the human mind. These theories predict that the arrow of time has no direction during unconscious processing states. Across 7 experiments, we tested whether masked negative stimuli presented in the future lead to an unconscious avoidance reaction in the present. Response registration took place about 500 milliseconds before stimulus onset. In the majority of the studies the predicted retroactive influence was found. On average, participants were able to unconsciously avoid negative future outcomes (mean ES = 0.07; Combined Bayes factor = 293). These results are in line with similar precognitive avoidance effects recently reported by Daryl Bem in 2011 (Experiment 2). The reported findings are discussed with regard to the proposed quantum model of the mind. We also highlight the limitations of our research.*

Keywords: retrocausation; precognition; quantum mind; consciousness; Orch-OR model.

Correspondence:
Prof. Dr. Markus Maier, University of Munich, Department of Psychology, Leopoldstr. 13, 80802 Munich, Germany. Phone: +49-89-2180-5215.
Email: markus.maier@psy.lmu.de

[1] Department of Psychology, Ludwig-Maximilians-University, Munich, Germany.

[2] Department of Medicine and Health Sciences, Universitat Internacional de Catalunya, Barcelona, Spain.

Journal of Consciousness Studies, **21**, No. 9–10, 2014, pp. ??–??

Introduction

Time is a fascinating concept in physics, and from Newtonian mechanics until today our understanding of it has dramatically changed. Whereas Newton (1687/1872) believed in the absoluteness of time independently of any frame of reference, Einstein (1905; 1916) in his relativity theory could show that time is not absolute but changes with the speed of an observer and with gravitation surrounding him. Furthermore, some physicists (e.g. Hawking and Penrose, 1996) argue that the mathematical formalism of quantum theory allows time to be undirected for quantum states. Past, presence, and future seem to lose their classical meaning in these areas of physics.

Recently, even in psychology very similar violations of the classical 'flow of time' concept have been reported. Bem (2011) published a series of nine experiments in which precognition, an ability to know or feel future events that are unpredictable from a classical perspective, was demonstrated. According to the author of these studies, such findings are caused by retroactive influences from future mental experiences into the past. In other words, time seemed to flow backwards in these experiments. These findings — if they were replicable — would dramatically change our model of mental functioning and might cause a paradigm shift in psychology. Consequently, the research community reaction was highly sceptical (Alcock, 2011; Carey, 2011a,b; Wagenmakers *et al.*, 2011a), and replication attempts have been undertaken to carefully explore the reliability of Bem's (2011) findings (e.g. Galak *et al.*, 2012; Ritchie, Wiseman and French, 2012), at this time, without success.

The line of research and the empirical findings presented in this article aimed to explore precognitive effects similar to those reported by Daryl Bem. By the time we started this research project in 2007, we were not aware of Bem's research activities. Our predictions were solely derived from theories combining quantum mechanical formalisms with mental processes (e.g. Penrose, 1989; 1994). Our core proposition was that retro-causal influences from the future into the past can be found in unconscious information processing. During our research activities, we became aware of Bem's work. Thus, to some extent, the studies presented here are an 'unintended' replication of Bem's Experiment 2 with which our initial design has the highest degree of similarity. Since a theoretical framework was the starting point of our research, in the following sections we will first describe our model. After that, we will refer to Bem's work, the independent replication attempts, and the critics of his work. The critical arguments concerning methodological issues were included during the course of our research at the planning stage of our Study 2.

Quantum Mechanics and the Human Mind

There is a growing body of research in neuroscience, information theory, and psychology that introduces quantum mechanical formalisms into theories of cognition. Some of these approaches use the mathematical structure of quantum mechanics as a modelling instrument to describe conceptual knowledge structures and decision-making processes (Aerts, 2009; Pothos and Busemeyer, 2009; Busemeyer *et al.*, 2011; Trueblood and Busemeyer, 2012). Others propose that quantum mechanical processes take place in the brain, causing quantum-like phenomena, especially at the transition from unconscious to conscious thought (Penrose, 1989; 1994; Penrose and Hameroff, 1995; 2011; Hameroff and Penrose, 1996). Some others refer to weak versions of quantum mechanics as basic features of the human mind without any reference to brain activities (Atmanspacher, Römer and Walach, 2002; Römer, 2004; Filk and Römer, 2011; Atmanspacher and Filk, 2012).

For our research, we used the Orch-OR model of consciousness provided by Penrose and Hameroff (Hameroff and Penrose, 1996; for a recent description see Penrose and Hameroff, 2011), from which we derived the basic hypotheses for our studies. According to this theory, at an initial stage of information processing, unconscious thoughts exist in a superposition state before they enter consciousness. Superposition involves the simultaneous existence of different quantum states described by Schrödinger's wave function (Schrödinger, 1935) and metaphorically visualized by the famous Schrödinger's cat. During this early stage of information processing unconscious thoughts evolve as quantum superpositions between slightly differing space-times (Penrose, 1994). Each space-time geometry relates to one unconscious thought that has a specific potential of becoming conscious according to a probability function assigned to the superposed states. Under specific gravitational conditions, i.e. space-time separations, the superposition self-collapses and one of the potential unconscious processes becomes conscious. The collapse rate can vary from a few milliseconds but might normally occur at much slower pace, '*...say, one half a second or so, i.e. ~500 msec...*' (Penrose and Hameroff, 2011, p. 16). This gravitation-dependent collapse constitutes an objective reduction (OR) of the state vector, and hence stands in contrast to the Copenhagen Interpretation (CI — Bohr, 1928) or decoherence theory (Zeh, 1970), according to which an act of measurement, i.e. subjective reduction (SR), or environmental factors cause the collapse of the wave function.

Although in CI and decoherence theory the collapse occurs purely randomly, Penrose (1989; 1994) suggests that objective reductions are not random, but influenced by information embedded in fundamental space-time geometry. Penrose identifies this information as Platonic values such as mathematical truth, ethical and aesthetic values along with precursors of physical laws, constants, forces, and intentions (Hameroff and Chopra, 2012). The non-randomness postulate not only provides the basis of free will (Hameroff, 2012; see also Eccles, 1994; Esfeld, 2000; Stapp, 2007), but also allows biological motives, such as harm avoidance, to unconsciously influence the outcome of the collapse. If a harmful and non-harmful unconscious experience exists in a superposed state of space-time geometries, the motive embedded as Platonic information might slightly influence the individual objective reduction, resulting in a deviation from randomness and serving the ultimate goal of survival. Thus, our first assumption was that our unconscious mind can automatically avoid *potentially* harmful events. Potential in the context of quantum mechanics means that the harmful experience exists in form of a pre-reality during the state of superposition (see Stapp, 2007).

Another important assumption in quantum mechanics also highlighted in the Orch-OR model (e.g. Penrose, 1989; Hameroff, 2012) is that during the state of superposition, quantum states evolve time-symmetrically (Penrose, 1989). The time-asymmetry, i.e. a specific direction of the arrow of time as we perceive it in our classical world, comes into existence after the collapse of the wave function due to an increase of entropy (*ibid.*). This implies that as long as our thoughts exist in the state of superposition, quantum information propagates in either direction in time (Hameroff, 2012). Thus, unconscious information processing would be able to know the future and react accordingly.

At first sight, the notion of information moving also backward in time (which implies that a signal travels faster than the velocity of light) stands in sharp contrast to Einstein's special relativity theory, according to which nothing can move quicker than the speed of light. However, this statement needs to be clarified a bit: No *classical* information — defined as a bit of 0 or 1 — can move faster than light, but as Gauthier and his colleagues (Stenner, Gaulthier and Neifeld, 2003; see Seife, 2006, pp. 149–50) could demonstrate, distorted information, which was made unreadable to some extent, moved faster than light speed and thus arrived at a detector before it was sent. The detector needed additional time to decode the bit, leading to the results that the classical bit could not be consciously detected quicker than light speed. So, for classical information, special relativity holds, but for degraded information the classical concept of causality can be violated.

The existence of a quantum superposition is a linear function of the extent to which information is available about the alternative states that constitute the superposition (Wang, Zou and Mandel, 1991). The more distorted the information about the single states is, and therefore the less classical (0/1) it is, the more ideal a superposition will be. Time un-directedness, which goes hand in hand with a state of superposition, appears thus to be a function of signal degradation. If a classical bit is equal to a conscious moment of knowing, any degraded information would be processed unconsciously since it is not fully consciously accessible. This means that the more unconsciously — i.e. not classically — a signal is processed, the more likely it travels backward in time. Since signal strength is also a function of degradation and awareness, this implies that the weaker a signal is, the more likely it travels backward into the past. Thus, retro-causal influences based on quantum mechanics should have a very small effect size and only findings that are small might be those that are reliable and reproducible. Of course, if a signal becomes too weak and unconscious, any effects might be undistinguishable from noise. Taken together, we agree with Greenstein and Zajonc (2006) that quantum information is unreadable in any classical sense. However, we also think that it is readable in a non-classical, unconscious sense.

The assumption that only unconscious knowledge can travel backwards in time has an important side effect. It prevents our physical world from the paradoxes that are involved in time travel. We cannot intentionally send back the correct answers of a test that we have failed because our professor usually keeps records about our performance in class, and because we are aware of the information that we would like to share with our past ego. However, we might be able to unintentionally send unconscious signals as long as they only unconsciously affect our behaviour and as long as they do not fully enter any observer's awareness during this process. Since solely the vaguely known elements of the past can be altered, no paradox will be observed.

In sum, our assumptions based on the Penrose and Hameroff's (Hameroff and Penrose, 1996; Penrose and Hameroff, 2011) approach were that unconscious information can unintentionally be transferred into the past and can unconsciously affect behavioural decisions as long as the individual is not aware of it. In addition, *potential* unconscious experiences that exist in a superposed state can retro-causally influence our past. Thus, the experimental design that we created to test this form of precognition had to make sure that: (i) the future signal did not enter consciousness and existed *potentially* (as a superposed form of pre-reality) and (ii) that the behavioural decision that should be affected in the past was also not based on conscious thinking. That is, any awareness at any stage of information processing from behaviour planning to signal perception had to be excluded in order to ensure these types of effects. In the method section, we will describe how we tried to achieve these goals.

The Phenomenon of Retroactive Influence of Future Events

Recently, our research community has been challenged by an article from Daryl Bem, published in the *Journal of Personality and Social Psychology*, that provided empirical evidence for the existence of an 'anomalous retroactive influence of some future event on an individual's current responses…' (Bem, 2011, p. 407). In a series of nine experiments using five different paradigms, he demonstrated that classically unpredictable future stimulus presentations had an effect on participants' responses preceding these presentations. For example in Experiment 2 participants had to indicate their preference for one of two neutral pictures (an original and its mirror image) by pressing a key on the keyboard. After the key-press a randomly chosen negative or positive masked picture was presented subliminally three times. The hypothesis was that if the individual unconsciously 'knows' or feels the future consequence of his or her preference judgment, he or she should be more likely to choose that neutral picture from the pair that leads to the presentation of a masked positive picture. This should lead to a better than chance (50%) avoidance of a subsequent negative masked picture presentation. The results were in line with the predicted avoidance of negativity effect: on average, less negative subliminal pictures were presented than expected by chance. Similar retroactive influences of future events were found for precognitive selection (forced choice) of erotic stimuli (Experiment 1), time-reversed evaluative priming (Experiment 3 and 4), retroactive habituation (Experiment 5 and 6), retroactive induction of boredom (only marginally significant, Experiment 7), and retroactive facilitation of recall (Experiment 8 and 9). In the latter two experiments, future practice of some items had a positive effect on recall performance for these items in a preceding memory task. One of the memory studies yielded the highest effect size ($d = 0.42$, Experiment 9) and was considered to be the easiest of the nine experiments to be replicated. As explicitly suggested by Bem (2011), several independent research teams tried to replicate the retroactive memory practice effects (Robinson, 2011; Galak *et al.*, 2012; Ritchie, Wiseman and French, 2012). These replication attempts took into account most of the critical arguments raised in response to Bem's work focusing on various statistical issues (Alcock, 2011; Wagenmakers *et al.*, 2011a): they predetermined sample sizes and avoided optional stopping and multiple analyses. In addition, they used the same data analytical strategies, usually simple t-tests, and the same procedure and methods as in Bem's original publication. With few exceptions, almost all of the early replication attempts failed. Galak *et al.* (2012) did a meta-analysis including also unpublished replication attempts (Milyavsky, unpublished data; Snodgrass, unpublished data; Subbotsky, unpublished data; Tressoldi *et al.*, unpublished data) that revealed no evidence for retroactive influences in the facilitation of recall paradigm. Thus, it seemed that the effects reported by Bem were not robust and the existence of precognition effects was called into question. At this point, serious doubts arose whether similar replication failures can be expected for the other studies reported by Bem (2011).

However, a meta-analysis of all forced-choice precognition experiments by Honorton and Ferrari (1989) that included 309 experiments which were quite similar to the design of Bem's Experiment 1 reported a small but significant precognition effect (but see Hyman, 1985). In addition, Mossbridge, Tressoldi and Utts (2012) did a meta-analysis that included 26 studies on the effect of predictive physiological anticipation of unpredictable stimuli. They found an overall significant retroactive influence of emotionally arousing stimuli on various kinds of physiological reactions. This might be considered as a conceptual replication of Experiment 2 in Bem's article in which a similar anticipatory emotional preparedness effect, i.e. avoidance, was found. Furthermore, Rouder and Morey (2011) did a meta-analytic Baysian analysis on several types of Bem's experiment. They found some evidence that individuals can avoid negatively valenced pictures. In addition, a recent meta-analysis including both published and unpublished replication attempts of Bem's experiments was conducted by Tressoldi *et al.* (submitted). They found an average ES of 0.10 (Hedges' g) in favour of precognition.

Taken together, it seems that, given the actual empirical data, retroactive facilitation of recall might not be a robust effect, whereas the empirical validity of retroactively influenced forced choices and emotional stimulations remains still open.

The Present Studies

The goal of the studies presented here was to test some of the propositions made by theories combining quantum mechanical phenomena with unconscious information processes (e.g. Penrose, 1989; 1994; Hameroff and Penrose, 1996; Penrose and Hameroff, 2011). The basic idea was that unconscious information transfer is time-symmetric and therefore future unconscious experiences can influence past responses (see also Mensky, 2011). Such time-reversed effects should exist only as long as the individual is not aware of any processes neither during the state of perception nor during response selection. Since alternative unconscious thoughts are proposed to exist in a state of superposition before a moment of consciousness occurs, they appear to constitute potential realities coexisting in different space-time geometries. This implies that even a potential pre-real mental experience can have an effect on response selections. In addition, the collapse of the superposition state is non-random, i.e. it can be influenced by information embedded in the space-time geometries allowing biological motives such as harm avoidance to influence humans' responses accordingly. A series of seven experiments have been performed to test these assumptions.

We would like to emphasize that the empirical studies reported here do not provide a full test of the Penrose and Hameroff approach, especially our test leaves aside the biological mechanisms proposed by the authors. Furthermore, similar predictions can be derived from the Atmanspacher, Römer and Walach (2002) model of the human mind. Thus, we do not test models against each other, but try to test some of the core assumptions of theories relating quantum formalisms with the human mind. Until the planning stage of Experiment 2 of our research project, we were not aware of Bem's (2011) studies. Initially, our project was not designed as a replication attempt. However, our study design coincidentally bears strong similarities to Bem's Experiment 2. The studies can thus be viewed as an 'unintended' replication attempt. Most of the critics of his work have been considered and its consequences implemented into our research project starting with the planning phase of Experiment 2 (Alcock, 2011; Wagenmakers *et al.*, 2011a) and the same analysis techniques have been used as those reported by Bem (2011; see also Ritchie, Wiseman and French, 2012).

Study 1

Method

All the research presented in this article involved human subjects and was conducted according to the ethical standards of the American Psychological Association (APA). Data were analysed anonymously. The studies received approval from the Ethics Committee at Stony Brook University and from the Ethics Committee at the International University of Catalunya, Barcelona. Written consent was obtained from participants run under the Stony Brook approval. Verbal consent was obtained for the rest of the participants run under the Barcelona approval. Verbal consent was considered to be sufficient, since it was ensured that data were recorded and analysed anonymously. The individuals' verbal consent was obtained after reading the instructions to the experiments. The experimenter asked for the participant's consent and emphasized that they would receive their credit also if they decided not to participate in this study. Participants were also told that they could stop and leave the experiment at any point in time. This consent procedure was approved by the Ethics committee.

In our first experiment, we investigated whether an unconscious choice of two alternative response options can be influenced by the future consequence of this choice. Participants had to press two keys on the keyboard simultaneously. For each trial each key was randomly assigned to either a positive or negative masked picture presentation that appeared after the key-press. Our hypothesis was that if participants unconsciously feel the future outcome of their action, they should unconsciously avoid negative pictures and more often select the positive alternative presentation. Although we were not aware of Bem's (2011) work at the time of planning the study and data collection, our Study 1 conceptually replicates Experiment 2 in his publication.

Participants

111 undergraduate and graduate students (88 female, 23 male; mean age = 22.7 years, SD = 3.67) participated in this study for course credit. They were recruited through the department's announcement board and through handouts in psychology classes. Students were told that participation involves three different experiments assessing

psychological mechanisms, but no more study details were given in the recruitment information.

Materials

Software and Computer

The study was conducted using an HP Compaq 6005 Pro MT computer, a Samsung Sync Master 204B 20'' monitor (56 Hz) and an HP keyboard. Eprime 2.0 software for designing psychological experiments was used for response registration and picture presentation. The left and right cursor keys served as response registration device. The keyboard was placed on the table in front of the participants with the cursor keys being centred to the midpoint of the computer monitor. The monitor was placed at a distance of about 50 cm to the participant.

Stimuli

The stimulus pictures were taken from the International Affective Picture System (IAPS] (Lang, Bradley and Cuthbert, 2008), which provides an experimental set of 1169 digitized photographs with normative rating scores (using a 9-point rating scale) on valence and arousal. A set of 10 extremely negative (mean = 1.73; *SD* = 0.27) and 10 extremely positive pictures (mean = 7.57; *SD* = 0.52) were selected based on the normative valence ratings (see Appendix for details).

Experimenters

Only informally trained undergraduate research assistants were used as experimenters. They were double blind, i.e. they did not know about the goal of the study, nor did they know anything about the pictures used in this experiment.

Procedure

Each participant was tested individually in a quiet lab room. Light was dimmed in the windowless room. The study described here was the final experiment in a series of three studies. Study 1, a paper-pencil task, and Study 2, a computer task, explored standard psychological effects and took about 20 minutes. After the completion of the two studies, participants were informed about Study 3. A written instruction was presented on the screen:

> 'In the following experiment you have to press two keys on the keyboard as simultaneously as possible. You will see this instruction on the monitor's screen:
>
> Please Press the Keys

> While seeing this instruction, please press both keys as simultaneously as possible!
>
> Afterwards coloured stimuli will be presented which you should simply watch.'

After the participant had read the instructions, the experimenter explained that the participant should put their index fingers on the left and right cursor keys of the keyboard. Both keys were placed on the table in front of the participant exactly at the same horizontal position as the midpoint of the computer screen. The experimenter emphasized that both index fingers should slightly touch the cursor keys throughout the experiment, and once the command appears they should press both keys as simultaneously as possible. Participants were informed that there is no rush, but the response should be spontaneous, and that after the key-press they should simply watch the following presentation of a coloured stimulus.

Each trial started with the key-press command presented on the screen. Once the key-press was performed, the command line disappeared and, after a 500 msec delay with a black screen, a masked positive or negative picture was presented. The masked picture presentation consisted of three consecutive stimulus presentations. First, a masking stimulus was presented for 72 msec, followed by the presentation of a negative or positive picture for 18 msec, again followed by the same mask for 72 msec. Each negative and positive picture was combined with an individual mask. The masking stimulus was constructed by dividing the original picture into small squares that were randomly rearranged. The resulting mask consisted of the same colour and lightness properties as the original picture and could therefore effectively mask the content of the picture ensuring a subliminal presentation. After the second masking stimulus had disappeared, a 3000 msec inter-trial interval appeared before the key-press command initiated the next trial. A total of 60 trial presentations were used in this study. The 60 experimental trials were preceded by three practice trials with neutral pictures helping the participants to familiarize themselves with the task.

Although participants were told to press both keys simultaneously, due to the design of a typical computer keyboard, one of two keys is always triggered first. Thus, in any given trial, either a left or a right key-press was registered even though participants subjectively performed a simultaneous two-key-response. In half of the trials, triggering a left key resulted in a positive masked picture presentation and a right key to a negative one. In the other half, key and valence assignment were exactly reversed. The randomization procedure provided by Eprime was used to randomize the order of trial presentation (PRNG). The 10 positive and 10 negative pictures were randomly assigned to each trial with the restrictions that each picture could maximally be presented 6 times within a study (i.e. if a participant always ‘chooses’ a positive picture presentation, 60 [6 x 10] positive pictures would be presented). Randomized trial selection was performed at the beginning of each trial.[3] After the completion of the 60 trials participants saw each masked picture presentation again and were asked after each whether they could recognize anything and, if so, what. None of the participants in each of the experiments reported below could precisely name the content of any picture. Thus, our masking procedure met the criterion of subjective unawareness.

Results

In line with aforementioned arguments, we hypothesized that if participants unconsciously feel the future outcomes of their unconscious choices, they should better than chance (50%) avoid a negative future masked picture presentation and approach a positive one. Following Bem (2011), Galak *et al.* (2012), and Ritchie, Wiseman and French (2012), a one-sample t-test with one-tailed alpha level was used for data analysis in this and all subsequent studies. Sample size was not determined before data collection in Study 1. Also, data analysis was performed twice on the sample. The first data analysis was done after data from 73 participants had been collected. A one-sample t-test with mean number of negative masked picture presentations as dependent variable revealed a mean of 48.81% (SD = 6.06) negative masked picture presentations, which was significantly below the 50% chance level, $t(72) = -1.67$, $p = 0.0495$, $d = 0.19$. We decided to check the robustness of this finding by increasing the sample size to more than one hundred. Our research assistants were told to invite more participants to the lab until a minimum of one hundred was reached. This resulted in a total number of 111. With this complete data set, a second analysis was performed. To accommodate the significance level to our multiple testing strategy, an alpha level of 0.025 (0.05/2) was used. The second analysis again revealed a significant effect. The mean score for negative masked picture presentations was 48.57% (SD = 5.65), $t(110) = -2.66$, $p = 0.0045$, $d = 0.25$.

---

[3] Experimentally forcing the left/right positions of the target to be equal ensures an equal likelihood for positive and negative picture presentations for both keys. However, a downside of this is that it destroys the statistical independence of the trials by using a sampling-without-replacement or ‘closed deck’ procedure.

Discussion

The data seem to indicate that on average participants were able to unconsciously avoid a negative future outcome and approach a positive one. Importantly, every process, starting from action control to perception of the experimental stimuli, was kept unconscious. It seems that an individual's unconscious mind works like a guide through the virtual environment. At present, we do not know whether the effect is caused by retroactive processes. Alternative explanations that are related to the use of a PRNG as the randomization procedure cannot be excluded at this point. We will refer to this issue in the introduction to Study 4 in this article and in the General Discussion. In addition, a major weakness of this study was the lack of predetermination of the sample size which opens the possibility to optional stopping, which in turn biases the likelihood of detecting significant effects (Alcock, 2011). Although this argument does not apply to the way we collected and analysed our data in Study 1, we agree that a predetermination of sample size based on power estimations is absolutely essential when testing such effects.

Study 2

Method

Material, design, and procedure were the same as in Study 1 with the one difference that the 10 negative pictures from Study 1 were used together with neutral instead of positive pictures. The neutral pictures were taken from the International Affective Picture System (IAPS; Lang, Bradley and Cuthbert, 2008) and have been selected based on the normative valence ratings (mean = 4.90; *SD* = 0.27; see Appendix for details).

Participants

A power analysis using G*Power 3.1.3 (Faul *et al.*, 2007) was used to determine the sample size of Study 2. At this time, we knew about Bem's work and therefore used the effect size $d = 0.20$; that is, the same effect size Bem found in his Experiment 2, which is most similar to our study design and matches closely the effect size we found in our Study 1. To reach a power of 80% (Cohen, 1988) the analysis based on this effect size revealed a sample size of at least 199 participants. We told our undergraduate research assistants to collect data from a minimum of 200 subjects and then to stop data collection.

201 undergraduate and graduate students (128 female, 71 male, 2 individuals did not indicate their sex; mean age = 21.4 years, *SD* =

4.39) participated in this study for course credit. Again, they were recruited through the department's announcement system and through handouts in psychology classes. Students were told that participation involved three different experiments assessing psychological mechanisms, but no more study details were given in the recruitment information.

Results

A one-sample t-test with mean number of negative masked picture presentations as dependent variable was used to analyse the data. The mean score was 48.94% (SD = 5.03), and the analysis revealed a significant deviation from 50%, $t(200) = -2.99$, $p = 0.0015$, $d = 0.21$.

Discussion

The results of Study 2 replicate the findings of Study 1 and Bem's Experiment 2 (Bem, 2011). Participants were able to better than chance avoid negative future outcomes.

Study 3

Next, we decided to test the avoidance effect with a much bigger sample size. Hence, we used a web-based program that invited participants who were interested in psychological tests to participate in our study on an internet platform. Individuals were told that the study was about spontaneous responses.

Method

Material, design, and procedure were the same as in Study 2 with three differences: statements about the placement of the keyboard and the use of the index fingers were included into the written instructions at the beginning of the experiment, and the time between key-press and masked picture presentation was varied between subjects from 400 msec to 650 msec in steps of 50 msec. Participants were randomly assigned to one of these delay conditions. Furthermore, instead of Eprime, the experiment was programmed using the computer language Flash Actionscript.

Participants

Since we did not know the size of our expected effect when data collection was made with a community sample via the internet, we did not use a power analysis for determining the sample size in advance. Rather, we decided to run as many participants as possible and stop data collection after a three-month period. Once this period ended, data were taken from the internet and analysed. 1222 individuals (865 female, 354 male, 3 individuals did not indicate their sex; mean age = 22.68 years, *SD* = 9.36) voluntarily participated in this study.

Results

A one-sample t-test with mean number of negative masked picture presentations across all delay conditions as dependent variable was used to analyse the data. The mean score was 49.62% (*SD* = 5.57) and the analysis revealed a significant deviation from 50%, $t(1221) = -2.37$, $p = 0.009$, $d = 0.07$. The effect did not systematically vary with the delay condition.

Discussion

The results of Study 3 replicate our previous findings and Bem's (2011) Experiment 2 results with a community sample. Participants were able to better than chance avoid negative future outcomes. The effect size was much smaller than in the other studies. This could be due to the fact that the circumstances under which our participants performed the study were much less controlled than in our lab studies (see also Galak *et al.*, 2012).

Unsuccessful Replication Attempts

During the whole project three more studies have been run in which our replication attempts failed. One pilot study was done after Study 1 (before knowing about Bem's work) by a graduate student who slightly changed the written instructions. The term 'coloured stimuli' was replaced by 'positive, negative, or neutral pictures'. Material, design, and procedure were the same as in Study 2. No significant effect was obtained within this study (N = 63; we stopped because the end of summer classes was reached). The mean score for negative masked pictures was 50.05% (*SD* = 4.52), $t(62) = 0.09$, $p = 0.54$. Our post-hoc explanation was that the change in wording jeopardized the unawareness of the masked pictures. We therefore changed the instructions back to the original statement in the subsequent studies. Another unsuccessful attempt was made after Study 2. In this study, we tried to explore the effects of individual differences in cortisol level on the avoidance effect. We predetermined the sample size with a power analysis using G*Power 3.1.3 (Faul *et al.*, 2007). We expected a correlation of $r = 0.18$, based on Bem's correlation between sensation seeking and the avoidance score in his Experiment

2 (Bem, 2011), and wanted to reach a power of at least 95%. This resulted in a sample estimation of 391. We told our research assistants to run a minimum of 400 subjects. Data collected from 406 participants revealed no significant avoidance effect ($M = 50.13$; $SD = 5.35$), $t(405) = 0.48$, $p = 0.68$. A third unsuccessful replication was obtained with another web-based study that was run after the first web study. Material, design, and procedure were the same as in the initial web study with two changes. Instead of trial randomization without replacement, a replacement procedure was used, i.e. the exact equal distribution of negative pictures to the left and right response key across the 60 trials was abandoned. A second change involved the use of only a 450 msec delay between key-press and masked picture presentation. Again, after a three-month period data were taken from the internet platform and analysed. 640 individuals participated in this study. The analysis yielded only a statistical trend for an avoidance effect. The avoidance mean score was 49.53 ($SD = 9.10$), $t(639) = -1.32$, $p = 0.094$, $d = 0.05$.

Taken together, up to this point six studies were run testing the avoidance effect. We found the predicted effect in three studies, whereas two studies obtained a null finding, and one study only a trend. At this point, our research team was unsure whether we had found a real effect here or not. We therefore decided to run one final decisive, highly powerful study in which also trial randomization was optimized.

Study 4

In this study, we tried to replicate our findings from Study 2 and 3 with a more sophisticated randomization procedure. According to Bem (2011), the strictest test of precognition or retro-causal influence is reached by the combined use of a predefined randomized list of trials (PRNG) and a hardware-based true random number generator (RNG). A quantum based number generator (QRNG) from id Quantique was used which can be found at www.idquantique.com. This hardware device passed both DIEHARD and NIST tests of randomness and is actually one of the most powerful ways to generate true random numbers (Turiel, 2007). Using this device, for each individual session a random list of 60 bits (0/1) was constructed and stored. Each bit corresponded to one trial in our experiment in the order it was created initially, i.e. trial 1 was related to the first bit, trial 2 to the second, etc. In addition, during each trial, directly after the key-press of the participant the RNG that was connected to the computer randomly created another bit (0/1). Since Quantis does not operate with a buffer, it was ensured that the actual bit used was always created after the key-press. The combination of initially created bits from the list and the actual RNG then defined whether a negative masked picture appeared after a left or after a right key-press. In this way, participants could not 'algorithmically know' the consequence of their response before or during the key-press. Any avoidance effects that might be found now could only be explained by precognition or retro-causal effects from the future (see Bem, 2011).

Method

Material, design, and procedure were the same as in Study 2 with two differences: the randomization procedure was optimized as described in the previous paragraph. In addition, a colleague informed us that older keyboards can have biases with regard to the sensitivity of the cursor keys. We therefore made sure to use a keyboard that was equally sensitive on both the left and the right cursor key, i.e. it produced 50% lefts and rights when pressed without subsequent picture presentations. This pre-test was made with a few participants from an independent sample.

Participants

A power analysis using G*Power 3.1.3 (Faul *et al.*, 2007) was used to determine the sample size of Study 4. The analysis indicated that 327 participants were required to reach a power of 95% given an effect size of $d = 0.20$. We told our undergraduate research assistants to collect data from 327 subjects and provided random lists for 327 sessions.

327 undergraduate and graduate students (237 female, 85 male, 5 individuals did not indicate their sex; mean age = 22.25 years, SD = 3.78) participated in this study for course credit or a small monetary reward. Again, they were recruited through the department's announcement system and through handouts in various classes. Students were told that participation involves three different experiments assessing psychological mechanisms, but no more study details were given in the recruitment information.

Results

One student did not complete all of the trials but stopped after 52. His/her individual avoidance score in percentage was therefore based on a total of 52. A one-sample t-test with mean number of negative masked picture presentations as dependent variable was used to analyse the data. The mean score was 49.36% (SD = 6.38), and the analysis revealed a significant deviation from 50%, $t(326) = -1.82$, $p = 0.035$, $d = 0.10$.

Discussion

The results of this study replicate the findings of Study 2 and 3 with a more state-of-the-art randomization procedure. On average, participants were able to avoid a negative future outcome. Such an avoidance effect obtained with this design can only be explained by retro-causal influences from future masked picture presentations (see Bem, 2011). This implies that the arrow of time had no direction during unconscious information processing as postulated by several theorists (see e.g. Penrose, 1989; Hameroff and Penrose, 1996; Penrose and Hameroff, 2011). Furthermore, assuming that neutral pictures do not elicit approach tendencies, the avoidance of negative masked pictures indicates that a stimulus that has been anticipatorily avoided (and therefore has not been presented) had an effect on a preceding unconscious response selection. Thus, the results imply that even 'potentially' presented stimuli can have an effect on human behaviour. Effects of potential realities existing in a state of superposition (Stapp, 2007) nicely fit to the suggested quantum mechanical explanation of unconscious and conscious information processing.

The observed effect size obtained in this study is much smaller than in Study 1 and 2. One reason might be that in the first two lab studies a closed deck procedure was used compared to an open deck approach in Study 4. Any biasing factors such as pressing one key only produces in a closed deck design a regression towards the 50% base rate thus reducing the error variance, whereas in an open deck procedure the error is increased through such biases. This might also explain the differences in the standard deviations between Study 1 or 2 and 4.

Meta-analysis of the Studies

Finally, we conducted a meta-analysis that included the results of all seven experiments that we conducted in this research project.[4] All meta-analytic statistical analyses were performed using Comprehensive Meta-Analysis version 2.2 (Borenstein *et al.*, 2005). The test of Heterogeneity reflected relative low heterogeneity, $I^2 = 49.78$, $Q = 11.95$ $p > 0.0632$. This result suggests that there is little heterogeneity across studies, justifying a fixed model. The results of the fixed model yielded a significant overall effect: ES = 0.07, 95% CI =

[4] We would like to thank Patrizio Tressoldi for conducting the meta-analysis with our data.

0.034–0.106, $z = 3.79$, $p = 0.0001$. In addition, we also performed an analysis based on a random model. This also revealed a significant effect with an overall effect size of ES = 0.08, 95% CI = 0.022–0.137, $z = 2.70$, p = 0.007. In sum, it can be stated that the mean effect size across studies is very small, but the avoidance of negativity is nevertheless significant overall and therefore can be considered to be a substantial effect. In addition, the mean effect size obtained in our studies presented here is in line with a meta-analysis recently performed by Tressoldi *et al.* (submitted) in which an average ES of 0.10 (Hedges' *g*) is reported.

Bayes-Factor Analysis

Some authors have argued that a frequentist statistical approach might not be the optimal method to analyse psi effects. Wagenmakers *et al.* (2011a) have explained the reasons in detail and we will not reiterate those here. The basic idea is that the strength of an evidence is not only dependent on the probability given that the H_0 is true, but might also be dependent in part on the likelihood of the effect given the H_1 is correct. Thus, 'in order to evaluate the strength of evidence that the data provide for or against precognition, we need to pit the null hypothesis against a specific alternative hypothesis and not consider the null hypothesis in isolation' (*ibid.*, p. 4). Bayesian t-tests were applied to our data in the following to achieve this goal (e.g. Rouder *et al.*, 2009). This test allows one to assess the strength of evidence for H_0 (i.e. no retroactive influence) versus H_1 (i.e. retroactive influence). In order to calculate the Bayes factor, a probability distribution for effect size, given H_1, needs to be specified. Wagenmakers *et al.* (2011a) used a Cauchy distribution on effect size that is centred around zero with scale parameter r = 1, that is $\delta \sim$ Cauchy (0, 1). However, this has been criticized by other authors (Bem, Utts and Johnson, 2011; see also Wagenmakers *et al.*, 2011b) since it overestimates the effect size of psi effects. We agree with some scientists arguing that a smaller r, for instance $\delta \sim$ Cauchy (0, 0.5) or $\delta \sim$ Cauchy (0, 0.1) might be more appropriate. According to our proposed theory described in the introduction, only very weak signals can be transferred from the future into the past. Therefore, the highest likelihood to obtain robust effects will be received by the weakest signal strength possible. This might be best reflected by an r of 0.1. We re-analysed our data of the seven studies with Baysian t-tests based on r = 0.1 and additionally did an analysis based on r = 0.5. In addition robustness analyses across a wider range of r (0 to1) have also been conducted (see Wagenmakers *et al.*, 2011b). To perform the Bayesian analyses, we used the R package provided by Morey and Rouder (2013). We also calculated a combined Bayes factor that summarizes the results of all seven experiments as suggested by Rouder and Morey (2011). In all analyses a one-tailed Bayesian approach was used based on the suggestions provided by Wagenmakers and Morey (submitted). In the following table the results of the Bayesian analyses are presented. Interpretations of the results in terms of evidence in favour of H_0 or H_1 were derived from Wagenmakers *et al.* (2011a).

Exp	BF $\delta \sim$ Cauchy (0, 0.1)	Evidence category (in favour of H)	BF $\delta \sim$ Cauchy (0, 0.5)	Evidence category (in favour of H)
Study 1	9	Substantial (H_1)	8	Substantial (H_1)
Study 2	21	Strong (H_1)	15	Strong (H_1)
Study 3	5	Substantial (H_1)	2	Anecdotal (H_1)
Unsuccessful attempt 1	0.54 (2)	Anecdotal (H_0)	0.18 (6)	Substantial (H_0)
Unsuccessful attempt 2	0.23 (4)	Substantial (H_0)	0.06 (17)	Strong (H_0)
Unsuccessful attempt 3	1	Neither (H_0 nor H_1)	0.27 (4)	Substantial (H_0)
Study 4	2	Anecdotal (H_1)	0.85 (1.2)	Anecdotal (H_0)
Combined BF	293	Extreme (H_1)	84	Very strong (H_1)

Table 1. Results of Bayesian t-test analyses (one-tailed) of the seven experiments (note: BF = Bayes Factor; H_0 = retroactive influence does not exist; H_1 = retroactive influence does exist).

Overall, the combined Bayes factor of 293 obtained with a $r = 0.1$, $\delta \sim$ Cauchy (0, 0.1) provided extreme evidence (BF > 100) in favour of H_1 (retroactive influence exists). R = 0.1 closely matches our proposed theory and is in line with our quantum theoretical model that only allows time-reversed effects when signal degradation and response options ensure the highest degree of exclusion of awareness and thus leads to a close to zero (but not completely zero) signal strength. Using $r = 0.5$, $\delta \sim$ Cauchy (0, 0.5) that is based on the expectancy of bigger retroactive effects possibly obtained when signal strength would be stronger revealed weaker evidence for the existence of retroactive influence (H_1). Figure 1 shows the variation of the combined Bayes factor across a wider range of r (0 to 1). Interestingly, evidence for H_1 decreased with the increase of the scale parameter r from 0 to 1 which is fully in line with our theoretical model. As a side note, Rouder and Morey (2011) who used an r of 1 for a Bayesian meta-analysis performed on Bem's (2011) retroactive avoidance of negativity results obtained a combined BF of 40. Their score closely corresponds to the combined Bayesian factor of 43 found within our data with r =1 (see Figure 1). Figure 2 provides a robustness analysis of the single Bayes factors separately for all seven experiments across a range of r from 0 to 1.

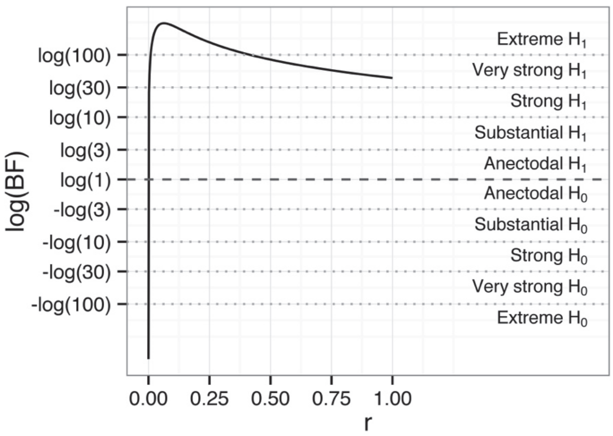

Figure 1. A robustness analysis for the combined effect across the seven experiments. The combined Bayes factor is plotted as a function of the scale parameter r of the Cauchy prior for effect size under H_1. The red dot indicates the result from r = 0.1, the horizontal dashed line indicates complete ambiguous evidence, and the horizontal dotted lines demarcate the different qualitative categories of evidence.

Data Repository

All raw data from the seven experiments reported in this paper can be accessed under the following link: http://www.psy.lmu.de/allg2/download/maier/mm_2013_rawdata.zip.

The password is: replication.

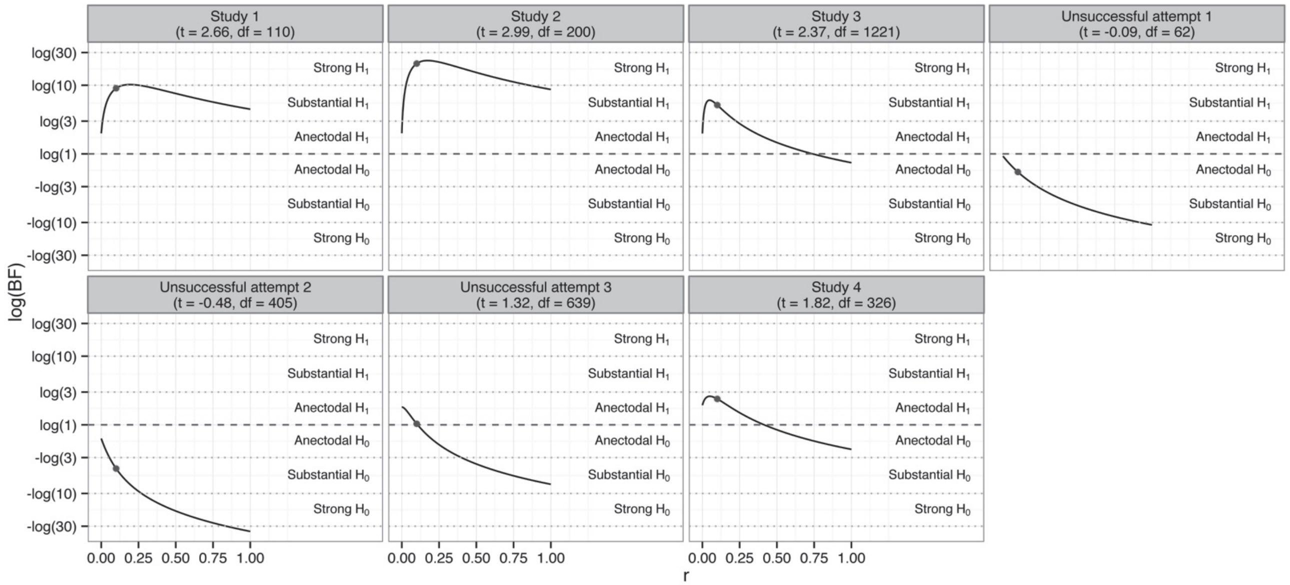

Figure 2. A robustness analysis for the seven experiments. The Bayes factor is plotted as a function of the scale parameter r of the Cauchy prior for effect size under H_1. The black dot indicates the result from r = 0.1, the horizontal dashed line indicates complete ambiguous evidence, and the horizontal dotted lines demarcate the different qualitative categories of evidence.

General Discussion

The goal of the studies presented here was to test some of the propositions made by theories combining quantum mechanical phenomena with unconscious information processes (e.g. Penrose, 1989; 1994; Hameroff and Penrose, 1996; Penrose and Hameroff, 2011; see also Atmanspacher, Römer and Walach, 2002; Römer, 2004; Filk and Römer, 2011; Atmanspacher and Filk, 2012). The basic idea was that unconscious information transfer is time undirected, and therefore future unconscious experiences can influence responses preceding those. In addition, it was assumed that unconscious thoughts temporarily (up to several hundred milliseconds) exist in a state of superposition until an objective reduction (Orch-OR collapse of the wave function) occurs. Such a reduction can non-randomly be influenced by information, e.g. motives, embedded in the space-time geometries that constitute the superposition (Penrose, 1989; 1994; Hameroff and Chopra, 2012). The motive was assumed to bias unconscious response selections in favour of the avoidance of negative picture presentations. In the following sections we will first relate our findings to this proposed model. Next, we will discuss alternative explanations of our findings that are related to the use randomization procedures.

Overall, the results were in line with our hypotheses. In a majority of four out of seven studies, we found small but reliable evidence for retroactive influences of unconscious signals. Randomly presented negative stimuli could anticipatorily be better than chance avoided. This effect was found with negative versus positive masked pictures (Study 1) and with negative versus neutral masked pictures (Study 2 to 4). The effect existed for college students (Study 1, 2, and 4) and for a community sample (Study 3) and could be documented by using different programming software: Eprime (Study 1, 2, and 4) and Flash Actionscript (Study 3). Interestingly, it was obtained with both pseudo-randomization (PRNG) procedures (Study 1 to 3) and with true random number generators (RNG, Study 4). Although some of our replication attempts failed, overall a small (average ES = 0.07; combined BF = 293) but significant/extreme avoidance effect could be documented. Two meta-analyses reporting similar precognitive reactions have recently been reported by Mossbridge, Tressoldi and Utts (2012) and Tressoldi *et al.* (submitted). Some authors (Lucadou, Römer and Walach, 2007) even argue that it is common to find null effects and a decline in effect size with non-classical effects.

It seemed that, on average, individual responses were influenced by future consequences and lead to an avoidance of potentially negative feelings. The Penrose-Hameroff model postulates that information that is embedded in the space-time geometries increases the likelihood for the realization of one of the superposed states. In our design, this information is identical to the motivational goal of harm avoidance. According to this view, the motive affected response selection by anticipating classically unpredictable, random negative events. The anticipation could only be effective if to some extend the future was 'known'. That is, individuals seemed to process unconscious information during a state of time-undirectedness that lasted approximately 500 msec. Such a finding is fully in line with some propositions made in the quantum models of the mind mentioned above.

Given the fact that such a mechanism is highly advantageous, the question might arise why the effect observed in our studies is so small and why we cannot easily detect such effects in our everyday lives. One central reason might be the strength of the signal that is transferred from the future. As we have described in the introduction, classical conscious information cannot be transferred quicker than the speed of light (Seife, 2006). However, non-classical, i.e. degraded, information — for which signal strength by definition must be weaker — can exceed the velocity of light and travel backwards in time (Stenner, Gaulthier and Neifeld, 2003; see also Seife, 2006, p. 149). According to the logic of quantum mechanics, the more degraded and thus the weaker a signal is, the more likely it behaves quantum-like (see Wang, Zou and Mandel, 1991), and therefore the more likely it is to be time-undirected. This leads to the paradoxical result that the weaker a signal is (i.e. the closer to zero it is), the more reliable a retro-causal effect might be. In the studies reported herein, we tried to obtain a maximum of degradation by minimizing any form of awareness during picture perception by using the lowest presentation time possible together with a powerful masking procedure. Awareness was also excluded during the process of decision making by using a simultaneous key-press design that involuntarily and not recognizably produced left or right key response decisions. Furthermore, participants were not aware of the relationship between key-press and picture outcome. To explore the causal role of awareness on retroactive effects, more experimental research is necessary in which the degree of awareness during perception of the future stimulus and during response selection is manipulated. According to our theory, the size of these retroactive effects should vary with such manipulations.

The finding of precognitive avoidance of negativity is also in line with the idea of superposed space-time geometries representing alternative unconscious thoughts which coexist simultaneously in potential realities as proposed by the Penrose and Hameroff approach. In our design, during each trial two potential realities evolved: one containing a negative, the other a neutral (or positive) future outcome. The unconscious mind seemed to timelessly experience both alternatives simultaneously in a state of superposition (Penrose, 1989; 1994). For example, in a given trial, the unconscious mind simultaneously 'knew' that a left key-press resulted in a negative masked picture presentation and the right key-press in a neutral. The experiences made in both alternative states of mind took place in potential realities which are different from classical, but nevertheless can have an effect on an individual's behavioural choice. From a classical perspective, they are pre-real in a sense that no classical, conscious information can be extracted from them (Stapp, 2007), but unconscious information can. The causal effectiveness of such a potential reality is nicely demonstrated by our findings that negative masked pictures were unconsciously avoided and therefore, from a classical standpoint, not presented, but nevertheless caused an avoidance reaction. In other words, something that is from a classical perspective non-existent had an effect on a previous response and thus must have existed in some non-classical, i.e. potential, form. This observation bears resemblance to the double slit experiment, one of the most basic experiments in quantum mechanics. In this experiment, quantum particles such as photons or electrons produced effects, the so-called interference pattern, that could have only been obtained if one quantum exists in different alternative states simultaneously. Schrödinger's wave function describes these states as a function of potentialities (Schrödinger, 1935). That is, the particle must have existed in one potential state and in a potential twin state at the same time, which is from a classical point of view impossible. In addition, the potential states must have interacted as if they were some kind of real state producing the interference pattern. Thus, potential states can have effects that can indirectly be measured. Such effects only occur as long as no classical information about the real state of a particle is derived from the experimental setting (Greenstein and Zajonc, 2006).

Finally, Penrose (1989; 1994) postulated non-random influences on the collapse of superposed states. In our studies, we found that a biological motive, harm-avoidance, biased the occurrence of purely randomly chosen alternatives (especially in Study 4 as a true random number generator was used). Such a finding is therefore in line with Penrose's idea of non-random objective reductions that are influenced by information embedded in fundamental space-time geometry (see also, Eccles, 1994; Esfeld, 2000; Stapp, 2007; Hameroff, 2012).

Similar effects of mental influences on superposition states in a double slit experimental design are reported by Radin *et al.* (2012).

Taken together, our results are in line with models of the human mind that combine quantum mechanical processes with unconscious processing such as the Penrose and Hameroff and also the Atmanspacher and Römer approach. Both approaches differ in the categorical differences the authors make or don't make between the mental and physical attributes of our world (see Hoche, 2008; Römer and Walach, 2011; Walach and Römer, 2000; 2011). Whereas Penrose and Hameroff do not propose such a distinction, the researchers around Atmanspacher, Römer, Hoche, and Walach do. In any case, our data are not a test of the quantum nature of the human mind, nor do they test models against each other. It is one important piece of the puzzle exploring the quantum mind, and our results provide some incremental evidence for the argument that it makes sense to further investigate quantum models in psychology.

The Use of Randomization Procedures

The question whether our studies provide evidence for retroactive influences is strongly related to the question of whether the assignment of key-presses (left/right) to future masked picture presentations (negative/other) could have been anticipated by any other process than precognition. The answer to this depends on the type of randomization used in our experiments. Bem provides an extensive discussion of this issue (Bem, 2011, pp. 410–1). We will summarize his arguments in the following and relate them to our procedures.

Randomization of a sequence of trials can be obtained by random functions included in the experimental software used in the experiments. Such a procedure is called a Pseudo Random Number Generator (PRNG) since it uses a complex mathematical algorithm which is predetermined and therefore, in principle, predictable. Although complexity and lack of knowledge of the initial starting number (the seed) reduces predictability, it cannot fully be ensured that the trial sequence and thus key–picture assignment was not classically knowable. In Study 1 to 3 such a computer-based PRNG was used, which implies that the precognitive avoidance effect observed could have also been caused by our participants' knowledge of the underlying algorithm. However, this alternative explanation seems to be unlikely since it would imply that the implicit understanding of the pseudo-randomization involves (i) some knowledge about the masked picture's content, (ii) a strategic influence on response selection during the simultaneous key-press, and (iii) rudimentary knowledge about the relation between key-press and picture presentation. In our studies, participants were not informed that key-press and picture presentation are related. We rather described both as two independent tasks. In addition, the need for simultaneous key responses were emphasized to participants, which should have reduced any strategically biased key selections. We cannot completely rule out this alternative explanation and someone might prefer this interpretation to any paranormal effects.

In Study 4, we used a hardware-based random number generator (from id Quantique; www.idquantique.com) that uses a quantum mechanism to produce truly random sequences (RNG). This hardware device passed both DIEHARD and NIST tests of randomness (Turiel, 2007). The RNG was used in our study to produce a list of 60 binary digits (0/1) for each participant before the experiment and the RNG also produced a bit (0/1) after each key-press. For the after key-press randomization no buffer storage was involved and random digits were taken to assign keys to the stimuli at the moment they were created. Only the combination of both randomly produced digits defined the key–picture assignment after the participant's key-press. Since the strongest tests of randomness have been passed with this equipment, predictability was definitively zero. This implies that any avoidance of negativity effect obtained with such a randomization procedure can only be attributed to retroactive influences (see Bem, 2011). Note, the use of double randomization as described above also rules out other paranormal influences such as clairvoyance or psychokinesis (for a more detailed discussion, see Bem, 2011).[5]

Taken together, although the effect is small, we unintentionally replicated similar findings from an independent research team (Bem, 2011). Furthermore, our findings were quite replicable within the same design, and the research strategy of using the same design and material within a series of studies has recently been postulated by Simmons and colleagues (guidelines for reviewers no. 4; Simmons, Nelson and Simonsohn, 2011). In addition, we had a theoretical starting point from which our predictions and the creation of the design have been derived (as postulated by Fiedler and Krueger, 2013). We also reported all studies that were run with this specific design and material. We predefined sample size and reached enough power to

[5] The randomization procedures used in all studies made sure that the left-right assignment of negative and positive/neutral pictures was purely random. Thus, any biasing influences of participants' handedness could not have produced the results described above. We also tested the influence of this factor in Study 4 and did not find any effect.

document the effect. Thus, we tried to seriously consider most criticisms that have been raised against Daryl Bem's work (Alcock, 2011; Wagenmakers *et al.*, 2011a; Asendorpf *et al.*, 2013). We know that the publication of these findings might again initiate a debate in psychology about the appropriate scientific way of dealing with such kinds of effects or psi in general. However, at the end of this series of experiments, we were also convinced that it would have been dishonest if we did not report our findings to the broader research community. At this point, we cannot foresee the future as to where this might lead…

Acknowledgments

We would like to thank Dr. Stephanie Lichtenfeld and Dr. Felix Schönbrodt for their support in the data collection, data analyses, and programing of the studies.

References

Aerts, D. (2009) Quantum structure in cognition, *Journal of Mathematical Psychology*, **53**, pp. 314–348.

Alcock, J. (2011) Back from the future: Parapsychology and the Bem affair, *Skeptical Inquirer*, **35**, pp. 31–39.

Asendorpf, J.B., Conner, M., De Fruyt, F., De Houwer, J., Denissen, J.J.A., *et al.* (2013) Recommendations for increasing replicability in psychology, *European Journal of Personality*, **27**, pp. 108–119.

Atmanspacher, H. & Filk, T. (2012) Contra classical causality: Violating temporal Bell inequalities in mental systems, *Journal of Consciousness Studies*, **19** (5–6), pp. 95–116.

Atmanspacher, H., Römer, H. & Walach, H. (2002) Weak quantum theory: Complementarity and entanglement in physics and beyond, *Foundations of Physics*, **32**, pp. 379–406.

Bem, D.J. (2011) Feeling the future: Experimental evidence for anomalous retroactive influences on cognition and affect, *Journal of Personality and Social Psychology*, **100**, pp. 407–425.

Bem, D.J., Utts, J. & Johnson, W.O. (2011) Reply: Must psychologists change the way they analyze their data?, *Journal of Personality and Social Psychology*, **101**, pp. 716–719.

Bohr, N. (1928) The quantum postulate and the recent development of atomic theory, *Nature*, **121**, pp. 580–590.

Borenstein, M., Hedges, L.V., Higgins, J.P.T. & Rothstein, H.R. (2005) *Comprehensive Meta-analysis*, version 22, Englewood, NJ: Biostat.

Busemeyer, J.R., Pothos, E.M., Franco, R. & Trueblood, J.S. (2011) A quantum theoretical explanation for probability judgment errors, *Psychological Review*, **118**, pp. 193–218.

Carey, B. (2011a) Journal's paper on ESP expected to prompt outrage, *New York Times*, p. A1.

Carey, B. (2011b) You might already know this, *New York Times*, p. D1.

Cohen, J. (1988) *Statistical Power Analysis for the Behavioral Sciencies*, 2nd ed., Mahwah, NJ: Lawrence Erlbaum Associates.

Eccles, J.C. (1994) *How the Self Controls Its Brain*, Berlin: Springer-Verlag.

Einstein, A. (1905) Zur Elektrodynamik bewegter Körper, *Annual Review of Physical Chemistry*, **17**, pp. 891–921.

Einstein, A. (1916) The basics of general relativity theory, *Annual Review of Physical Chemistry*, **49**, pp. 769–822.

Esfeld, M. (2000) Is quantum indeterminism relevant to free will?, *Philosophia Naturalis*, **37**, pp. 177–181.

Faul, F., Erdfelder, E., Lang, A. & Buchner, A. (2007) G*Power 3: A flexible statistical power analysis program for the social behavioral and biomedical sciences, *Behavior Research Methods*, **39**, pp. 175–191.

Fiedler, K. & Krueger, J.I. (2013) Afterthoughts on precognition: No cogent evidence for anomalous influences of consequent events on preceding cognition, *Theory & Psychology*, **23** (3), pp. 323–333.

Filk, T. & Römer, H. (2011) Generalized quantum theory: Overview and latest developments, *Axiomathes*, **21**, pp. 211–220.

Galak, J., LeBoeuf, R.A., Nelson, L.D. & Simmons, J.P. (2012) Correcting the past: Failures to replicate psi, *Journal of Personality and Social Psychology*, **103**, pp. 933–948.

Greenstein, G. & Zajonc, A.G. (2006) *The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics*, 2nd ed., Sudbury, MA: Jones and Bartlett.

Hameroff, S. (2012) How quantum brain biology can rescue conscious free will, *Frontiers in Integrative Neuroscience*, **6**, p. 93.

Hameroff, S. & Chopra, D. (2012) The quantum soul: A scientific hypothesis, in Moreira-Almeida, A. & Santana Santos, F. (eds.) *Exploring Frontiers of the Mind–Brain Relationship*, pp. 79–97, New York: Springer.

Hameroff, S. & Penrose, R. (1996) Orchestrated reduction of quantum coherence in brain microtubules: A model for consciousness, *Mathematics and Computers in Simulation*, **40**, pp. 453–480.

Hawking, S.W. & Penrose, R. (1996) *The Nature of Space and Time*, Princeton, NJ: Princeton University Press.

Hoche, H.-U. (2008) *Anthropological Complementarism: Linguistic, Logical, and Phenomenological Studies in Support of a Third Way Beyond Dualism and Monism*, Paderborn: Mentis Verlag.

Honorton, C. & Ferrari, D.C. (1989) Future telling — a metaanalysis of forced-choice precognition experiments 1935–1987, *Journal of Parapsychology*, **53**, pp. 281–308.

Hyman, R. (1985) The Ganzfeld psi experiment: A critical appraisal, *Journal of Parapsychology*, **49**, pp. 3–50.

Lang, P.J., Bradley, M.M. & Cuthbert, B.N. (2008) *International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual Technical Report A-8*, Gainesville, FL: University of Florida Press.

Lucadou, W. v., Römer, H. & Walach, H. (2007) Synchronistic phenomena as entanglement correlations in generalized quantum theory, *Journal of Consciousness Studies*, **14** (4), pp. 50–74.

Mensky, M. (2011) Logic of quantum mechanics and phenomenon of consciousness, *Journal of Cosmology*, **14**.

Morey, R.D. & Rouder, J.N. (2013) Bayes Factor: Computation of Bayes factors for common designs, R package version 0.9.4, [Online], http://CRAN.R-project.org/package=BayesFactor

Mossbridge, J., Tressoldi, P. & Utts, J. (2012) Predictive physiological anticipation preceding seemingly unpredictable stimuli: A meta-analysis, *Frontiers in Psychology*, **3**, pp. 390–390.

Newton, I. (1687/1872) *Philosophiae naturalis principia mathematica [German translation: Mathematische Prinzipien der Naturlehre]*, Wolfers, J.P. (trans.), Berlin: Oppenheim.

Penrose, R. (1989) *The Emperor's New Mind*, Oxford: Oxford University Press.

Penrose, R. (1994) *Shadows of the Mind: A Search for the Missing Science of Consciousness*, Oxford: Oxford University Press.

Penrose, R. & Hameroff, S. (1995) What gaps? Reply to Grush and Churchland, *Journal of Consciousness Studies*, **2** (2), pp. 98–112.

Penrose, R. & Hameroff, S. (2011) Consciousness in the universe: Neuroscience quantum space-time geometry and Orch-Or theory, *Journal of Cosmology*, **14**.

Pothos, E.M. & Busemeyer, J.R. (2009) A quantum probability explanation for violations of 'rational' decision theory, *Proceedings of the Royal Society B: Biological Sciences*, **276**, pp. 2171–2178.

Radin, D., Michel, L., Galmadez, K., Wendland, P., Rickenbach, R. & Delorme, A. (2012) Consciousness and the double-slit interference pattern: Six experiments, *Physics Essays*, **25**, pp. 157–171.

Ritchie, S., Wiseman, R. & French, C. (2012) Failing the future: Three unsuccessful attempts to replicate Bem's 'Retroactive facilitation of recall' effect, *PloS One*, **7**, pp. 1–5.

Robinson, E. (2011) Not feeling the future: A failed replication of retroactive facilitation of memory recall, *Journal of Social Psycholgy Research*, **75**, pp. 142–147.

Römer, H. (2004) Weak quantum theory and the emergence of time, *Mind and Matter*, **2**, pp. 105–125.

Römer, H. & Walach, H. (2011) Complementarity of phenomenal and physiological observables: A primer on generalised quantum theory and its scope for neuroscience and consciousness studies, in Walach, H., Schmidt, S. & Jonas, W.B. (eds.) *Neuroscience, Consciousness and Spirituality*, pp. 97–107, Dordrecht: Springer.

Rouder, J.N., Speckman, P.L., Sun, D., Morey, R.D. & Iverson, G. (2009) Bayesian t tests for accepting and rejecting the null hypothesis, *Psychonomic Bulletin and Review*, **16**, pp. 225–237.

Rouder, J.N. & Morey, R.D. (2011) A Bayes factor meta-analysis of Bem's ESP claim, *Psychonomic Bulletin and Review*, **18**, pp. 682–689.

Schrödinger, E. (1935) Die gegenwärtige Situation in der Quantenmechanik [The present situation in quantum mechanics], *Naturwissenschaften*, **23**, pp. 807–812, 823–828, 844–849.

Seife, C. (2006) *Decoding the Universe: How the New Science of Information is Explaining Everything in the Cosmos from Our Brains to Black Holes*, New York: Penguin Books.

Simmons, J.P., Nelson, L.D. & Simonsohn, U. (2011) False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant, *Psychological Science*, **22**, pp. 1359–1366.

Stapp, H.P. (2007) *Mindful Universe: Quantum Mechanics and the Participating Observer*, New York: Springer-Verlag.

Stenner, M.D., Gauthier, D.J. & Neifeld, M.A. (2003) The speed of information in a 'fast light' optical medium, *Nature*, **425**, pp. 695–697.

Trueblood, J.S. & Busemeyer, J.R. (2012) A quantum probability model of causal reasoning, *Frontiers in Psychology*, **3**, p. 138.

Turiel, T.P. (2007) Quantum random bits generators, *American Statistical Assocation*, **61**, pp. 255–259.

Wagenmakers, E.J., Wetzels, R., Borsboom, D. & van der Maas, H.L.J. (2011a) Why psychologists must change the way they analyze their data: The case of

psi: Comment on Bem (2011), *Journal of Personality and Social Psychology*, **100**, pp. 426–432.
Wagenmakers, E.J., Wetzels, R., Borsboom, D. & van der Maas, H.L.J. (2011b) Online appendix for: Why psychologists must change the way they analyze their data: The case of psi: A robustness analysis, [Online], http://www.ejwagenmakers.com/papers.html.
Walach, H. & Römer, H. (2000) Complementarity is a useful concept for consciousness studies: A reminder, *Neuroendocrinology Letters*, **21**, pp. 221–232.
Walach, H. & Römer, H. (2011) Generalized entanglement — A nonreductive option for a phenomenologically dualist and ontologically monist view of consciousness, in Walach, H., Schmidt, S. & Jonas, W.B. (eds.) *Neuroscience, Consciousness and Spirituality*, pp. 81–95, Dordrecht: Springer.
Wang, L.J., Zou, X.Y. & Mandel, L. (1991) Induced coherence and indistinguishability in optical interference, *Physical Reviews A*, **44**, pp. 4614–4622.
Zeh, H.D. (1970) On the interpretation of measurement in quantum theory, *Foundations of Physics*, **1**, pp. 69–76.

Paper received October 2013; revised January 2014.

Appendix

Neutral	Negative	Positive
7004	3000	1440
7006	3010	1603
7035	3051	2050
7050	3053	2070
7090	3060	2311
7150	3062	2550
i07185	3064	4660
7233	3068	4676
7234	3071	5001
7235	3168	5600

Table 2. Picture numbers from the Lang *et al.* (1999) International Affective Picture System used in the experiments.

Conflict of interest statement

Our research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions

MM proposed the underlying theory and predicted the effect. He invented the study design and wrote the manuscript.

VB contributed to the theory, helped in programing the experiments and data analysis. She proofread the draft and added corrections.
CK helped in the development of the design, did the programming of Study 1, and supported data collection of Study 1. He proofread the draft and added corrections.
MP ran the studies, contributed to the theory and helped in analysing the data.
MF-C ran Study 7 and proofread the draft.
MG-S ran Study 7 and proofread the draft.