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RESEARCH ARTICLE

Observer Effects on Quantum Randomness: Testing Micro-Psychokinetic Effects of Smokers on Addiction-Related Stimuli

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Abstract—A vivid discussion revolves around the role of the human mind in the quantum measurement process. While some authors argue that conscious observation is a necessary element to achieve the transition from quantum to classical states during measurement (Wigner 1963), some go even further and propose a more active influence of the human mind on the probabilities of quantum measurement outcomes (e.g., Atmanspacher, Römer, & Walach 2002, Penrose & Hameroff 2011). This proposition was tested in micro-psychokinesis (micro-Pk) research in which intentional observer effects on quantum random number generators (RNGs) were investigated. In the studies presented here, we extended this line of research and tested the impact of unconscious goals on micro-Pk. Our focus was cigarette addiction as an unconscious drive, and we hypothesized that regular cigarette smokers would influence the outcome of a quantum RNG that determined whether the participant was going to see a smoking-related or a neutral picture. Study 1 revealed strong evidence for micro-Pk (BF = 66.06), supporting H_1. As expected, no deviation from chance was found with non-smokers. In Study 2, a pre-registered highly powered replication attempt failed to reproduce this result and showed strong evidence for H_0 (BF = 11.07). When the data from both studies are combined, a remarkable change in effect across time (resembling a combination of appearance followed by decline) can be seen only in the smokers' subsample. Appearance and decline effects were absent in the non-smokers' sample and in a simulation. Based on von Lucadou's Model of Pragmatic Information, we suggest that (micro-)Pk effects follow a systematic pattern comparable to a dampened harmonic oscillation. This concept may shed new light on past and future Pk research.

Keywords: micro-psychokinesis—observation—quantum measurement—mind–matter

Introduction

Theories about the relation between mind and matter belong to the hot topics of current science. Some early interpretations of quantum physics located a possible mind–matter interaction at the measurement process of quantum states. Wigner and von Neumann for instance suggested that the act of measurement was only complete when conscious observation of the result has taken place. They argued that conscious observation was the central factor causing the collapse of the wave function, i.e. the transition from quantum to classical states (e.g., Wigner 1963). This transition apparently occurs in a probabilistic fashion (Born 1926). Thus, consciousness was supposed to determine the collapse but not the exact outcome. Although mainstream quantum physics regards quantum-randomness as ontic and inherent in nature (Greenstein & Zajonc 2006), newer theories and empirical findings challenge this view (see Varvoglis & Bancel 2015). According to this research, intended observers might be able to influence the outcome of a quantum experiment. The goal of the studies presented here was to test the effect of motivated observation on quantum processes and to explore corresponding deviations from quantum randomness.

The first discovery of quantum theory started when Plank (1900) detected that energy was quantized and postulated as a "Wirkungsquantum" (quantum of action). Since then through the groundbreaking work of leading physicists such as Bohm, Bohr, Born, de Broglie, Dirac, Einstein, Feynman, Heisenberg, Pauli, Schrödinger, von Neumann, Wheeler, Wigner, and many others, this theory has evolved into a mathematically well-defined framework explaining many phenomena of the micro-world with an astonishingly high degree of accuracy (Byrne 2010, Greenstein & Zajonc 2006). One dramatic implication of this theory constitutes the probabilistic behavior of quantum systems when a measurement takes place. The act of a measurement turns a deterministically evolving quantum state into a probabilistically transformed existence within the macro-world. For example, before a measurement is performed, the place of an electron can be described through a wave function, the Schrödinger equation (Schrödinger 1935). It summarizes all potential locations of the electron within the system, treating them as a superposition. During the act of measurement this electron is found in one specific place only with a probability exactly corresponding to the square of the amplitude of the wave function (Born 1926). This probabilistic nature of the results of an observation is considered to be a basic principle inherent in quantum mechanics. Randomness at the level of a detector signal cannot be attributed to any inaccuracy of the measurement process but is a true and fundamental aspect of nature (but see Bohm 1952, Broglie 1927, 1953). There is apparently no yet-unknown underlying principle (so-called 'hidden

variables') as proposed by Einstein who was unsatisfied with a probabilistic nature ("God does not play dice") explaining or causally affecting this random behavior (Bell 1964).

Some authors have challenged this proposition, arguing that the human mind plays a central and active role during the measurement process that goes beyond being responsible for the transition to happen. Under specific circumstances, mental processes related to consciousness presumably influence the likelihood of an outcome of a quantum process, leading to slight deviations from randomness. Those scientists revised the standard quantum theory accordingly. Atmanspacher, Römer, and Walach (2002), for instance, developed the Generalized Quantum Theory (GQT) (see also Atmanspacher & Filk 2012, Filk & Römer 2011, Römer 2004). In this framework, a measurement is characterized by an epistemic split that occurs when pre-consciously experienced potential quantum alternatives are transferred into conscious knowledge about one of them. This knowledge transfer can be shaped by the observer's mindset. Observer effects are thus described as entangled correlations between observer and the observed system (von Lucadou & Römer 2007). As a consequence, non-random deviations are allowed, but they should decline shortly after their first detection as will be explained more in depth later. Another revision, the orchOR theory, has been proposed by Penrose and Hameroff (2011) (see also Hameroff 2012, Hameroff & Penrose 1996, Penrose 1989, 1994). In their theory, the act of measurement constitutes an objective reduction of the wave function leading to the emergence of a conscious moment when realizing the result of the measurement. These reductions are at the quantum level gravitation-dependent and mathematically described as small curvatures between space–time geometries that represent the potential quantum states. The authors assume that objective reductions are not random and can be influenced by specific information embedded in fundamental space–time geometry. Penrose identifies these as Platonic values that among others include mental concepts (Hameroff & Chopra 2012). Thus, intentional observers might be able to non-randomly influence the transition of potential quantum states into one specific classical state. Similarly, Stapp (2007) equates measurement with the act of conscious observation (see also Wigner 1963) and proposes a conscious choice of the quantum alternatives during the measurement process. Mensky (2011, 2013) takes a different route and provides an extension of the Everettian interpretation of quantum mechanics (Everett 1957). Here he assumes a corrective process, called post-correction, that allows an individual to navigate through the potential quantum worlds. He termed this mechanism 'super-intuition'. Although this might not be an exhaustive list of the revisions of quantum theory, all these

approaches have in common that they postulate a correlation between a mental state of the human mind and the outcome of a quantum experiment. This specific mind–matter interaction will be tested in the studies presented here and has been an empirical challenge for researchers for many decades. Their work has become known as micro-psychokinesis research. We will review and highlight their main findings in the following paragraphs.

Micro-Psychokinesis

Psychokinesis research has a long history and dates back to the early work of Crookes, Horsley, Bull, and Myers (1885), Crookes (1889), James (1896), Richet (1923), and Schrenck-Notzing (1924) during the late 19th and early 20th centuries. In these early years, case study reports and field investigations involving participants who mentally tried to move objects dominated the field (see Varvoglis & Bancel 2015). Later on, in the Rhine era, more scientifically designed studies testing mental effects on random sources such as dice tosses were performed (e.g., Rhine 1944, Rhine & Humphrey 1944). However, it took until the 1960s when the first experimenters used quantum states as a source for true randomness (Beloff & Evans 1961). In this early stage, participants were prompted to influence a quantum superposition of a decayed and non-decayed radioactive state to intentionally slow down or speed up the rate of decay. Random number generators that produced numerical outcomes based on quantum sources, so-called true RNGs (tRNGs), became a standard tool in this area of research (Jahn, Dunne, & Jahn 1980, Schmidt 1970a) and have been accompanied by the development of quantum theoretical explanations for psychokinesis ever since (e.g., von Lucadou & Kornwachs 1977, Schmidt 1975, Walker 1975).

During that time the term micro-psychokinesis was born. According to Varvoglis and Bancel (2015),

> micro-psychokinesis can be defined as mental influences on inanimate, probabilistic systems, producing effects that can only be detected through statistical means. The target systems may include tumbling dice, coin tossing systems, or hardware random number generators (RNGs). (p. 266)

Numerous studies have been performed since then testing intended observer effects on true, i.e. quantum, random number generators' outcomes and leading to a vast amount of data even until recently (e.g., Tressoldi et al. 2014). The majority of these studies used an instructed intention protocol where participants were prompted to influence the RNG in a way that produced a specific non-random visual or auditory outcome. Since we

are primarily interested in intended observer effects on quantum systems, we will focus only on research findings obtained with true random number generators (tRNGs). Also, for clarity purposes we decided to summarize the results by referring to aggregated data reported in several meta-analyses authored by the most prominent research groups and skeptics in the field (for an excellent overview, see Varvoglis & Bancel 2015).

The first meta-analysis reported micro-psychokinesis effects of individual mental activity on various kinds of random sources (Radin & Nelson 1989). The 597 experimental studies reported covered a time range from 1959 to 1987 and included experiments using tRNGs but also algorithmically based random number generators, so-called pseudoRNGs. The overall effect size ES ($\times 10^{e-4}$) was always greater than 2 and significantly different from zero for various analyses, indicating that on average mental activity during intended observation had an effect on random outputs in these studies. This meta-finding was confirmed by a followup meta-analysis reported by Radin and Nelson (2003) in which the database was updated with 176 new studies. A more recent meta-analysis by Bösch, Steinkamp, and Boller (2006) included only studies that tested the effect of intended human interactions with tRNGs. This is the only and most complete summary of research investigating mental effects on quantum randomness exclusively. The final analysis of 380 experimental studies covering the years from 1961 to 2004 revealed a significant but very small and heterogeneous overall effect size. This confirmed the results of the earlier meta-analyses that documented an overall micro-psychokinetic effect on different types of RNGs, but this time focusing on tRNGs only. It could be interpreted as tentative evidence favoring the idea of intended observer effects on quantum randomness. However, the authors also observed a correlation between sample size of the studies and their effect sizes. Given the heterogeneity, the small overall effect, and this correlation, the authors speculated that the meta-analytic effect could be due to publication bias (but see Radin, Nelson, Dobyns, & Houtkooper 2006). This raised some doubts about the validity of the effect reported by this meta-analysis. Although many proponents of micro-psychokinesis (e.g., the Princeton Engineering Anomalies Research program PEAR) share a policy of open data and reporting data from all studies that have been conducted—long before the publication crisis reached mainstream psychology and led to the same recommendations—this argument always reappears when new findings or new evidence are presented.

Another, yet more convincing, empirical argument against micro-psychokinesis is the astonishing lack of successful direct replications. One prominent example for this is the Jahn, Dunne, and Nelson (1987) benchmark

experiment done at the PEAR laboratory. It involved data from 2.5 million trials from 91 participants collected over 12 years of research. At the end of the study, they had found a highly significant effect of intended observation on tRNGs, yielding a z-score of 3.8. In 1996 a consortium consisting of two research groups the Grenzgebiete der Psychologie und Psychohygiene at Freiburg and at the Center for Behavioral Medicine at the Justus-Liebig University of Giessen started a three-year exact replication attempt. Data involving 750,000 trials per condition from 227 participants were collected and reported by Jahn et al. (2000). The results were disappointing since the overall z-score obtained was not significant. Micro-Pk of this type appeared to not be replicable, and this and similar failures increased skepticism toward PSI. However, a closer inspection of the original PEAR data by Varvoglis and Bancel (2015) revealed that two highly performing subjects seemed to have contributed to about a quarter of the overall effect size observed. According to the authors, this incident led to an overestimation of the proposed average effect size in the population. As a result, the power estimation for the replication attempt was misleading. A much higher sample size would have been needed to document the effect in the replication study than the number that was actually used. Thus, a severely underpowered study served as the test for replicability. This important finding was largely ignored. As a consequence, the replication failure was considered as evidence that no robust effect could be documented.

Another way of dealing with replication failure was to identify potential moderators of the effect (e.g., Bösch et al. 2006), but in many cases this could not account for the failures. Not satisfied by giving up their beliefs in micro-Pk, some authors suggested that PSI effects for specific theoretical reasons cannot be documented objectively. Some argue that such effects are subjective and self-referential processes and objectivity standards of modern time science do not apply (see, e.g., Atmanspacher & Jahn 2003, Etzold 2004, Kennedy 2003). Von Lucadou (2006, 2015) provided an elaborate model that refers to the concept of "Pragmatic Information". In his framework, novelty and confirmation are considered to be complementary variables. This is true for data obtained with quantum systems that violate the no-signal theorem such as non-random effects on quantum states. Although such effects would be highly novel, they would quickly vanish (or re-appear somewhere else) when confirmation (i.e. replication) efforts were made. Declining effects should therefore be natural in micro-Pk. The main problem with this kind of theory is that the accumulation of scientific evidence would always need to decline and would thus be indistinguishable from replication failures obtained with null effects (Etzold 2004).

The findings within micro-Pk research seemed to be fluctuating, and

in the search for potential reasons we as trained experimentalists took one step back during the planning phase of our studies presented here and focused on the independent variable. The majority of the studies using tRNGs manipulated their participants' intentions toward the tRNG by giving explicit instructions such as "try to move up the graph" or "try to delay the decay". In this way the observer's consciousness was put into action assuming that it would affect the quantum random choices. The silent theoretical assumption behind this treats consciousness as being outside the physical reality influencing the physical quantum world like a "deus ex machina". This idea traces back to the origins of quantum mechanics where some researchers emphasized the role of the conscious observer to determine the quantum collapse while keeping the randomness postulate intact (e.g., Wigner 1963, see also von Neumann's position described in Byrne 2010). However, the revised quantum approaches reported above (e.g., Atmanspacher, Römer, & Walach 2002, Mensky 2011, Penrose & Hameroff 2011) regard consciousness only as a byproduct of the measurement process. In these theories both the classical outcome and its conscious experience emerge from a common quantum source during a measurement. Before the measurement takes place, unconscious knowledge of the potential states and quantum superpositions of the different states coexist. This idea was first described by the 'unus mundus' theory developed in a letter exchange lasting from 1932 to 1958 between C. G. Jung and W. Pauli (see Atmanspacher 2012). During quantum measurements, unconscious information and corresponding quantum states evolve into one specific conscious perception of one classical state (either gravitation-dependent: Penrose & Hameroff 2011; as an epistemic split: Atmanspacher, Römer, & Walach 2002; or through mental effort: Mensky 2011, 2013, Stapp 2007). Conscious mental occurrences together with quantum system outcomes are in this way entanglement correlations rather than causal effects. True causality takes place in the realm of the unconscious.

This theoretical gap between predictions and empirical practice has to some extent been overlooked in previous psychokinesis research. Nevertheless, there is some groundbreaking work that has pursued this idea of passive volitional effects on micro-Pk in the past. For example, the animal-psi work from Schmidt (1970b, 1973, 1979) and Peoc'h (1988, 2001) found micro-Pk effects with different animals. Others reported similar effects with human participants put into meditative (e.g., Bancel 2014, Radin & Atwater 2012, Tressoldi et al. 2014) or various emotional (e.g., Debes & Morris 1982) states. In addition, research that used 'hidden' RNGs also reported evidence for correlations between passive volitional or emotional states on outputs produced by unknowingly present trueRNGs. The most

impressive findings were obtained within the Global Consciousness Project which relates global events to RNG data (see http://noosphere.princeton.edu/results.html#alldata).

Early on, theoretical attempts were also made to explain these effects. The PMIR and 'conformance behavior model' (Stanford 1977) theoretically addressed these non-intentional characteristics of PSI by relating Pk events to the Jungian term 'synchronicity'. According to these models, individuals non-intentionally express their inner states through sudden environmental changes. The GQT (Atmanspacher, Römer, & Walach 2002) is just a more elaborate and mathematically refined version of these early ideas. For a recent overview of this area of research and its relation to the more conscious intention approach, see also Varvoglis and Bancel (2015).

The advantage of the GQT (e.g., Atmanspacher, Römer, & Walach 2002) above these early explanations of micro-Pk is that it breaks up the separation of observer and observed object and includes the observer of a tRNG into the working mechanics of the output generator. The observer with their unconscious desires and the tRNG with its potential outputs during the quantum processing stage are considered to form a unity within an experimental trial. This entity subsumes an undivided co-existence of potential quantum states and unconscious desires before a conscious observation takes place. The act of observation then non-randomly results in a state of perceiving one tRNG output that is more likely in line with the underlying desire.

From this perspective, the micro-Pk studies that used intentional instruction protocols, such as the Jahn, Dunne, and Nelson (1987) PEAR study and others, might also produce the expected effects but only if the participants were able to form intentions in a way that included simultaneous activations of corresponding unconscious desires. In other words, the intentional instruction protocol needed a two-step induction procedure to ensure success, whereas our goal was to directly activate the unconscious mode. This might also explain why there are often reports of strong individual differences in the traditional approaches as Varvoglis and Bancel (2015) found for the original PEAR experiment and which were also present in Schmidt's work. Only individuals who were able to deeply ground the artificially induced instruction into their selves and related unconscious system might be able to produce an effect in such designs.

Encouraged by these findings and based on the GQT (Atmanspacher, Römer, & Walach 2002), we thus proposed to directly manipulate the unconscious desire of our participants instead of their conscious intentions. This could be achieved by either manipulating the unconscious desire experimentally or pseudo-manipulating the unconscious desire by using pre-

established desires within certain individuals toward a specific state (that is a physical state that is correspondent to the desire). Hence, we designed the independent variable in our studies using a primarily unconsciously driven intentional state, the desire for cigarettes within smokers and compared it to non-smokers. We tested its effect on a tRNG that on each trial randomly chose pictures displaying either cigarette-related or neutral content. In this way, we tried to close the aforementioned gap as much as possible.

With regard to the direction of the effect, two opposite outcomes were equally likely. On one hand, the smokers' unconsciously rooted desire could affect the tRNG toward an increased likelihood for cigarette pictures. That is on average smokers should observe more of those pictures than expected by chance. No deviations from chance level were expected for non-smokers. Another completely opposite prediction was derived from the emotional transgression model, developed by the author MM. Since some smokers are addicted, they should have an unconsciously grieving drive toward cigarettes. On the unconscious level, they experience a permanent deficit of nicotine and therefore are convinced of not having enough of it most of the time. This unconscious fear of not "having enough" translates into a self-fulfilling prophecy of never getting enough. For smokers, this should on average result in a less-than-chance observation of cigarette pictures, an outcome that would reflect the deficit on the physical level. No statistically relevant deviations from chance were expected for non-smokers.

Since the direction of the effect investigated in our first study was unclear, we started with a two-tailed hypothesis stating that the average score of cigarette pictures should deviate from chance for smokers but not for non-smokers.

Study 1 Methods

All research presented was conducted in accordance with the ethical requirements of the American Psychological Association (APA). The instructions did not reveal the study's purpose, but ensured the data's anonymization and emphasized the participants' choice to withdraw from the experiment at any given time.

Consent

Voluntary participation was ensured, and written consent was obtained from all participants. If participants were interested, an explanation about the study's purpose was given individually after the tasks were completed. This procedure and the experiment were approved by the ethical board of the Department of Psychology.

Participants

In sum, 254 participants have been tested in the first study (145 female, 109 male; mean age = 30.3 years, *SD* = 12.88). The sample size was a result of the Bayesian sequential design that will be explained more in depth later. Participants were recruited through the department's announcement board, through handouts in psychology classes, through Facebook university groups, and through direct contact by the experimenters. Participants enrolled in the university's psychology bachelor's degree classes were able to acquire credits within their program.

Smokers and non-smokers were identified via self-assessment. Upon arriving at the experiment, all participants were asked to provide information about their smoking behavior. They were asked to choose between 'being a regular cigarette smoker' (at least 1 cigarette per day), 'being a smoker of other tobacco products' (e.g., pipe), 'being a casual smoker', 'being a non-smoker', and 'being a former smoker'. Only participants who smoked cigarettes regularly were labeled as smokers. Casual smokers, i.e. participants who smoked less frequently than daily, and former smokers were labeled as non-smokers. Also, smokers of other tobacco products (e.g., pipe) were assigned to the group of non-smokers since the addiction-related stimuli used in the experiment focused on cigarettes. In addition, the German version of the Fagerström Test for Nicotine Dependencies (FTND-G) (Schumann, Rumpf, Meyer, Hapke, & John 2003) was used to assess the degree of nicotine addiction within the group of smokers. Finally, the attitude toward smoking was assessed with all participants via a questionnaire containing 10 statements about smoking. Participants were asked to indicate their level of agreement toward positive (e.g., *smoking is fun*) or negative (e.g., *smokers smell badly*) statements. These two questionnaires were only used for exploratory purposes.

Materials

Software and computers. The study was conducted on a set of four different laptops that had all been prepared in an identical fashion. Due to this, differences in the presentation of the experiment were minimal at most, e.g., due to slight differences in the size of the display. The stimuli were presented on a black background with a size of 500 × 400 pixels. For this, a presentation procedure was programmed in C# that translated the output of the random number generator into choosing either smoking-related (cigarette) pictures or non-smoking pictures.

Stimuli. Non-smoking pictures were taken out of the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert 2008), which

provides an experimental set of 1,169 digitized photographs rated on arousal and valence using a 9-point rating scale. A set of 10 neutral (mean valence = 4.90, *SD* = 1.09) and unexciting (mean arousal = 2.61; *SD* = 1.86) pictures displaying everyday objects was chosen. Addiction-relevant stimuli (cigarette pictures) were taken out of the Geneva Smoking Photographs (GSP) (Khazaal, Zullino, & Billieux 2012), a normative database providing 60 addiction-relevant photographs for nicotine and tobacco research. A set of 10 pictures was chosen from the database providing variation in terms of product, smoking behavior, and tobacco-related cues (e.g., cigarette packs, ashtrays, smoking individuals, etc.).

Generation of quantum randomness. A tRNG, a quantum number generator (Quantis-v10.10.08) developed by the company ID Quantique from Geneva, was used (http://www.idquantique.com/random-number-generation/quantis-random-number-generator/). This apparatus produces quantum states by using photons that are sent through a semi-conductive mirror-like prism. The photon has an equal chance to be deflected in one or another direction producing a superposition of both states until a measurement is performed. Upon measurement, the photon is found on either route with a 50% probability which is then transformed into a numerical score such as 0 or 1, depending on the track it was found on (technically Quantis transforms 8 such bits into 1 Byte). This procedure is thus a reenactment of the famous double-slit study known in quantum physics testing the wave–particle duality. This hardware passed all serious tests of randomness such as the DIEHARD and the NIST tests (see certificates from various independent agencies on the website) and is one of the most effective tRNGs worldwide (Turiel 2007). In this way a true quantum source for randomness was established within each experimental trial.

Experimenters

For this study, informally trained research assistants were used as experimenters. Their task was to find smokers and non-smokers in equal numbers. They had only rudimentary knowledge about the aim of the experiment at the point of data collection. Data on smokers and non-smokers were randomly collected. The experimenters sent their raw data to the study supervisor on average every other day or so, depending on the number of participants tested.

Procedure

Participants were tested in different locations with mobile test stations. This was necessary since most student participants were non-smokers,

forcing experimenters to expand the participant pool beyond students. Experimenters made sure to test in a distraction-free environment with no other persons present. At the beginning of the experiment, experimenters read a written instruction to the participants:

> Thank you for participating in this experiment! In the first part of the study you will sit in front of the computer and look at pictures. I know that this can be very tiring, I ask you nonetheless to not get distracted and focus your attention on the computer for the whole time of this part. It is *absolutely necessary* for this experiment that you look at the pictures! This will take approximately 10 minutes. Of course you can quit the experiment at any time, should you feel uncomfortable.
>
> As soon as you have finished there will be a message on the screen. Please let me know, so I can prepare the computer for the second part of the experiment. This will be a questionnaire. Filling it out will take about 5 more minutes. All data are collected anonymously.
>
> Do you have any questions?

When the participant had no more questions, the experimenter opened the software and told the participant to start the display of the pictures by pressing the spacebar as soon as they were ready. To avoid any interference by the experimenters, they were instructed to stay aside and distract themselves mentally during the experiment while checking on the participant only once in a while.

Participants attentively observed a consecutive series of 400 photographs. A tRNG decided if the next photograph would be pulled out of the set of addiction-related stimuli or out of the neutral stimuli. A software program used the randomness process of Quantis to decide which of the stimuli in the chosen set would be displayed. Stimuli were chosen by sampling without replacement. This means in the second trial there were only 9 pictures to choose from in each set since the "partner image" in the set not shown would be dismissed as well, and in the third trial 8, and so on. After every 10th trial, all pictures had the same probability to be chosen again. This process ensured that each picture in either category had an equal chance to be displayed over the course of the experiment. Therefore, different aspects of smoking in the pictures had an equal chance to be displayed and affect the participant. Participants looked at a centered cue (700 ms) first, then at the addiction-related or neutral stimuli (400 ms), and finally at a black screen (400 ms). This process was repeated 400 times (see Figure 1).

After the completion of the picture-presentation, the experimenter opened a batch file that added a unique code to the data and connected the code to the questionnaire that was subsequently opened via a web browser.

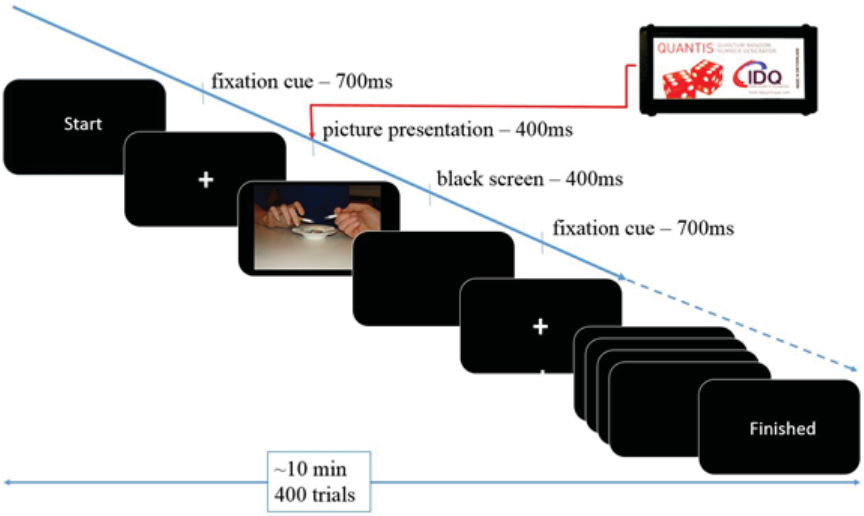

Figure 1. The 400 trials of the experiment consisted of the display of a fixation cue, a smoking or non-smoking-related picture, and a black inter-trial interval.

Data Analysis

Data collection and analysis was performed by using Bayesian inference techniques for hypotheses testing as recommended by Wagenmakers, Wetzels, Borsboom, and van der Maas (2011). The Bayesian theorem provides us with information on how to update our beliefs given new incoming data. Whereas the frequentist approach makes assumptions about theoretically repeated replications of the same study, the Bayesian method accumulates data concerning the effect and repeatedly updates the likelihood for an effect given the additional data. The strength of evidence for the effect is in this framework considered to be dependent on both the likelihood of the data given that H_0 is true as well as on the likelihood of the data given that H_1 is true. Thus, to find out whether the data provide more evidence for H_1 or for H_0, these two likelihoods are pitted against each other. The resulting score is called the Bayes Factor (*BF*) and resembles the relative amount of evidence that the data provide for or against a postulated effect. In this way, the existence and the non-existence of an effect can be tested against each other within the same dataset. A Bayes factor of 10 or higher is considered to indicate strong evidence for H_1 or H_0, respectively.

In order to calculate the Bayes Factor, a probability distribution for effect size that is centered around zero with scale parameter r needs to be specified a priori. This Cauchy distribution ($\delta \sim$ Cauchy (0, r)) identifies the prior, i.e. the likelihood of the data given there is an effect, i.e. p(data|H1). Wagenmakers et al. (2011) recommend an r equal to 1. The statistical software JASP designed to perform basic Bayesian analyses uses a default r of .707. Other authors recommend a lower r of .5 (Bem, Utts, & Johnson 2011) or of .1 (Maier et al. 2014) knowing that PSI effect sizes are usually very small (mostly in the range of .1 to .2). The choice of the prior provides a degree of freedom within the Bayesian approach. For data analysis in the studies presented here, we decided to use an r of .5, i.e. $\delta \sim$ Cauchy (0, .5). This score was determined before data collection was started.

Bayesian hypothesis testing comes with several valuable advantages. One is that the Bayes Factor combines information about the effect and the sample power within its score. A high *BF* can only be reached when sufficient power was provided through sample size, whereas the frequentist approach might accidentally detect an effect within a severely underpowered study. Thus, although the frequentist approach needs an a priori power analysis and pre-definition of sample size to compensate for this potential problem, the a priori definition of sample size is not necessary when applying Bayesian techniques. On the contrary, the Bayesian approach allows for data accumulation, i.e. additional subjects can be tested and included in the dataset until a pre-specified *BF* criterion for H_1 (or H_0) has been reached.

This also permits optional stopping after hitting the *BF* and is therefore a more effective way of hypothesis testing than the frequentist method. We decided to use a Bayesian sequential design with a *BF* of 10 as a stopping rule. The Bayes factor was monitored on a regular basis and data collection was stopped as soon as the stopping criterion was met. Nevertheless, additional data were available at this point and we decided to include all available data in our analysis, resulting in a slightly larger sample size than necessary. Since researchers in the field of psychology are more familiar with the frequentist approach and less so with Bayesian hypotheses testing, we outlined the reasons for using the Bayesian approach in the studies presented here in more detail. Before the study, we also decided to analyze the data with a Bayesian one sample *t*-test. For each subgroup, smokers and non-smokers, separate tests have been applied, each testing the respective sub-sample's mean score of cigarette pictures against chance level. For all Bayesian analyses, the statistical software tool JASP (Version 0.8.2) (JASP Team 2017) has been used.

Study 1 Results

In this first study, the authors of this paper disagreed about the expected direction of the effect tested here. On the one hand, it was proposed that smokers through their desire for cigarettes unconsciously attract pictures displaying those items. Hence, smokers should affect the random number generator to produce on average more than 200 cigarette pictures, since 200 was the expectancy value for purely random selections. On the other hand, the emotional transgression model views the desire for cigarettes within smokers as an anxious expression of a deficit, i.e. smokers supposedly believe they have actually not gotten enough of it. This in turn should be similar to a self-fulfilling prophecy and decrease the number of cigarette pictures being presented to smokers than expected by chance. Thus, a mean score of less than 200 could also have been expected. To account for the controversial predictions of both models, a two-tailed approach was chosen to test any substantial sample mean deviations from chance level. For non-smokers, null effects were expected, i.e. evidence for H_0 should be found.

Data for smokers and non-smokers were tested separately by one-sample Bayesian *t*-tests (two-tailed) with 200 as testing criterion and mean number of cigarette pictures as dependent-variable. As outlined above, data for each subsample were accumulated and repeatedly tested when new data came in until at least one Bayes factor of 10 or more was reached.

Smokers

The final Bayesian *t*-test analysis with 122 smokers yielded a *BF* of 66.06 for H_1. The mean score of cigarette pictures for these participants was mean = 196.7, *SD* = 9.87, indicating very strong evidence for the effect that participants who identified themselves as smokers viewed fewer smoking-relevant pictures than expected by chance. The graph below represents a sequential analysis of the Bayes factor for smokers (see Figure 2).

No significant correlations between the average mean score of cigarette pictures and the level of addiction measured with the Fagerström Test for Nicotine Dependencies nor between the score and the attitude toward smoking was found (see Table 1 in the Appendix).

Non-Smokers

The same analyses were performed with participants identifying themselves as non-smokers. The final Bayesian *t*-test analysis with 132 smokers yielded a *BF* of 6.13 for H_0. The mean score of cigarette pictures for these participants was mean = 200.5, *SD* = 9.68, indicating moderate evidence

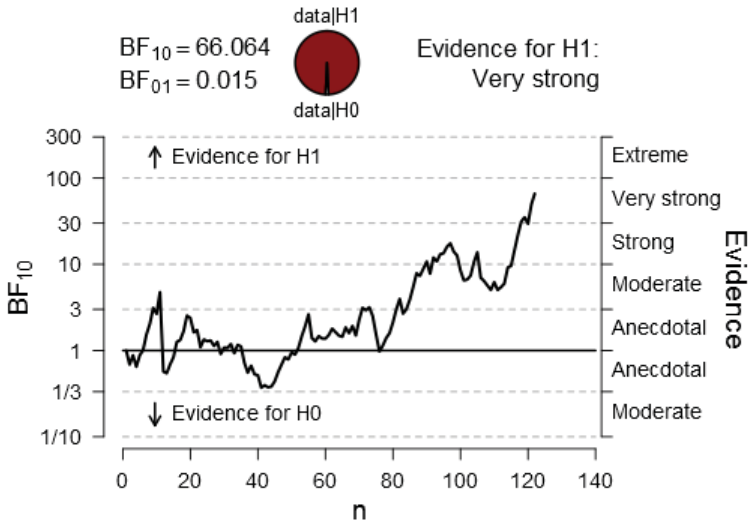

Figure 2. The curve displayed within the graph indicates the temporal change in BF when additional smokers were tested, i.e. when more and more evidence was included in the analysis.

for the null effect.[1] Participants who identified themselves as non-smokers viewed on average a number of smoking-relevant pictures around the chance level. The graph below represents a sequential analysis of the Bayes factor for non-smokers (see Figure 3).

From the beginning, a clear trend toward H_0 could be seen.

Study 1 Discussion

The results of Study 1 provide evidence for a very substantial deviation of the mean number of cigarette pictures from chance level within smokers. Smokers who passively observed the pictures chosen at each trial by a highly sophisticated and effectively working quantum random number generator seemed to unconsciously affect the quantum process toward non-randomness. They saw fewer cigarette pictures than was expected if the tRNG was working in a purely random fashion. Assuming that the generator was working properly, this would mean that motivated human observation can produce deviations in quantum randomness in line with their underlying desire. The data also support the emotion transgression model that predicted on average a negative deviation of smoking-relevant pictures for this group of individuals. A *BF* much higher than 10 also underlines the robustness of this effect. It states that it is 66 times more likely to obtain such data if H_1 is true than if H_0 was correct.

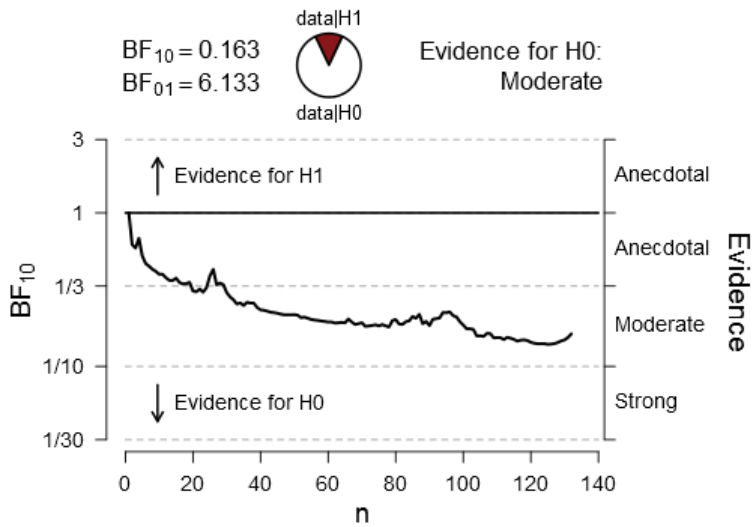

Figure 3. The curve displayed within the graph indicates the temporal change in BF when additional non-smokers were tested, i.e. when more and more evidence was included in the analysis.

For non-smokers, moderate evidence for a null effect was found supporting the idea of random presentations of the cigarette pictures on average across the trials. Since non-smokers should not have had any desire toward the picture sets, they should also lack any motivated observation. Thus, no influence on quantum choices was expected as reflected by the data of this subgroup. One could argue that non-smokers might have had strong rejecting attitudes toward cigarette pictures and should therefore also be considered to be motivated observers. However, we think that this attitude is not based in a deep physically grounded anti-desire as compared to the desire existent within smokers and therefore is not deeply enough rooted in someone's existence. Our model of motivated observation restricts mind-quantum randomness interactions to those deeply rooted motives and goals only. This is supported by a correlation, r = .05 (BF_{01} = 10), between attitude toward smoking and the number of smoking-related pictures within the overall non-smokers group, indicating strong evidence for no impact of this attitude on non-random picture presentations.

Overall, the data are in line with our predictions and with similar research documenting effects of the human mind on quantum random number generators (for an overview, see Varvoglis & Bancel 2015).

To test the robustness of the effect reported above, we decided to do an exact replication of Study 1. Although replications are the cornerstone

of empirical research and although conceptual replications are available for micro-Pk (for an overview see, e.g., Bösch et al. 2006), there is a lack of successful one-to-one replications for a central experiment in micro-Pk research, the PEAR study (see Varvoglis & Bancel 2015).

This spectacular example involves the replication failure of an original experimental protocol developed and performed by the PEAR lab at Princeton University (Jahn, Dunne, & Jahn 1980). This study was attempted to be replicated by a combined research group from the Institute für Grenzgebiete der Psychologie und Psychohygiene at Freiburg and the Center for Psychobiology and Behavioral Medicine at Justus-Liebig University Giessen (Germany). The replication attempt failed and could not find evidence for intended observation on RNGs. Although Varvoglis and Bancel (2015) offered an explanation for the failure by proposing an overestimation of the original effect size due to outliers' data, a number of scientists also speculated about the inherent elusive manner of PSI effects, arguing that such mind–matter interactions involving the quantum realm are based on subjective and self-referential processes and cannot therefore be documented objectively (see, e.g., Atmanspacher & Jahn 2003, Kennedy 2003). Von Lucadou (2006, 2015) went further and provided a model based on the idea of Pragmatic Information proposing that quantum effects that violate the "no-signal theorem" need to vanish when researchers try to replicate them. According to him, the amount of initial novelty a data pattern contains with regard to this theorem is reciprocally related to the amount of later confirmation: The stronger the violation the quicker the disappearance (or re-appearance somewhere else) of this effect in an additional data collection.

Although superficially knowing about the hassle of replication in this area of research and the discussion around it, we ignored these warnings for two reasons: First, a *BF* of 66.06 gave us a pretty firm belief that the effect would show up again in an exact, careful replication. And second, if an effect was not replicable, any attempt at its empirical documentation would not make sense from the beginning. Since we had already done Step 1, we felt we had to do Step 2 as well.

Study 2 Methods

In Study 2 we performed an exact replication of Study 1. The study was pre-registered at the Open Science Framework (OSF) (https://osf.io/4fzq8). Procedural details, including selection of the participants, stimuli, apparatus, experimental protocol, and questionnaires used were the same as in Study 1. Also the statistical analyses were the same with one important change: The effect within the smokers in Study 2 was tested using a one-

tailed statistical approach. The reason for this change was that after Study 1 we had a clear prediction about the direction of the effect. We expected smokers to show a lower-than-chance deviation with regard to the mean number of cigarette pictures being observed. All these procedural details and statistical techniques were pre-specified in the preregistration. Again, a prior distribution of $\delta \sim$ Cauchy (0, .5) was used.

Apparatus, Stimuli, and Procedure

All experimental setups were the same as in Study 1.

Participants

In sum, 175 smokers and 220 non-smokers (208 female, 184 male, 3 chose not to specify their gender; mean age = 31.30, *SD* = 13.11) were tested in the second study. Acquisition strategy and their labeling were done in the same way as reported above. Data collection again was stopped as soon as a Bayes factor reached 10 in either direction, resulting in a similar but slightly larger sample size than in Study 1.

Consent

Voluntary participation was ensured, and written consent was obtained from all participants. If participants were interested, an explanation about the study's purpose was given individually after the tasks were completed. This procedure and the experiment were approved by the ethical board of the Department of Psychology.

Study 2 Results

Data for smokers and non-smokers were tested separately by one-sample Bayesian *t*-tests with 200 as the testing criterion and the mean number of cigarette pictures as dependent-variable. As outlined above, data for each subsample were accumulated and repeatedly tested when new data came in until at least one Bayes factor of 10 or more was reached.

Smokers

The final Bayesian *t*-test analysis with 175 smokers yielded a one-tailed *BF* of 11.07 for H_0. The mean score of cigarette pictures for these participants was *M* = 200.3, *SD* = 10.38, indicating strong evidence for the null effect. Smokers viewed an average number of cigarette pictures close to and not different from chance level. The graph below documents a sequential analysis of the Bayes factor for smokers (see Figure 4).

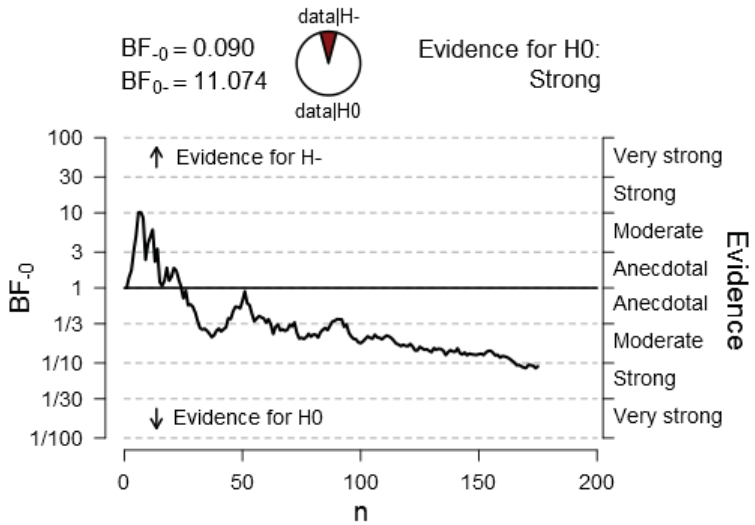

Figure 4. The curve displayed within the graph indicates the temporal change in BF when additional smokers were tested, i.e. when more and more evidence was included in the analysis.

No significant correlations between average mean score of cigarette pictures and the level of addiction and attitude toward smoking was found (see Table 2 and Table 3 in the Appendix for an analysis for both studies combined).

Non-Smokers

The same analyses were performed with participants[2] based on their self-reports being labeled as non-smokers. The final Bayesian *t*-test analysis with 220 non-smokers yielded a two-tailed *BF* of 3.74 for H_0. The mean score of cigarette pictures for these participants was mean = pictures around chance level. The graph below represents a sequential analysis of the Bayes factor for non-smokers (see Figure 5).

Study 2 Discussion

Contrary to our predictions made in the pre-registration phase of the study, the results of Study 2 did not replicate the effects found in Study 1. For smokers, strong evidence for the null hypothesis was revealed. Moderate evidence for the null effect was also found for non-smokers, which was in line with our predictions. It seems that the data pattern shown by the smokers is with each added subject consistently moving in the opposite

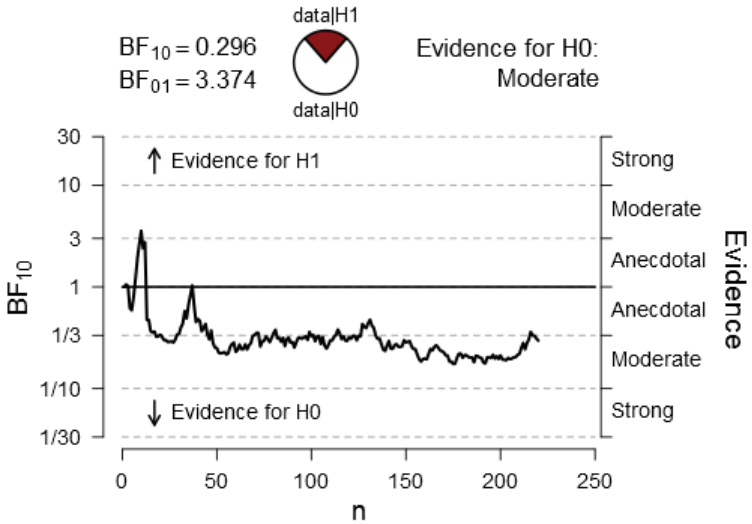

Figure 5. The curve displayed within the graph indicates the temporal change in BF when additional non-smokers were tested, i.e. when more and more evidence was included in the analysis.

direction of that found in Study 1. Although initially the effect was strongly present within the first 10 to 20 participants, it quickly dropped, and, given the mean score, even went in the opposite direction. Overall, applying the standards of scientific research we need to declare that the replication attempt clearly failed and a robust effect could not be determined.

When looking at the Bayesian sequential analyses (Figures 2 to 5) separately for smokers and non-smokers and separately for Study 1 and Study 2, some interesting patterns are noteworthy. Non-smokers in both studies uniformly show a null effect through the course of each experiment, indicated by a smooth asymptotic trend toward evidence for H_0. In contrast, Smokers in Study 2 who eventually revealed a clear null finding displayed a quite volatile trend before they hit the stopping criterion. Smokers within the first 20 participants in this group initially almost reached a $BF_{10} = 10$ in evidence for the H_1 before the trend went in the opposite direction. This is surprising and stands in contrast to all trends for non-smokers or any simulation performed (see below). Although random fluctuations might be a plausible explanation for this, it could also be considered as a hint that additional mechanisms might be at work. One potential explanation might be individual differences that might moderate the effect within the smokers between Study 1 and Study 2. This would imply that certain personality

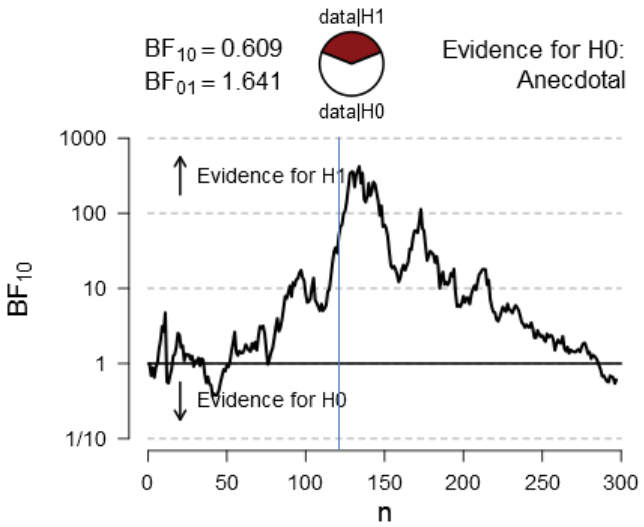

Figure 6. The curve displayed within the graph indicates the temporal change in BF when additional smokers were tested, i.e. when more and more evidence was included in the analysis. The transition from Study 1 to Study 2 is indicated by a vertical line at n = 122.

traits were strongly different in Study 1 compared with Study 2. Although we do not have empirical data to rule out this alternative explanation, we do not think that individual differences could fully account for the effect changes between the studies. One had to assume that a specific personality pattern would be present in the first experiment and an opposite one in the other. Such a homogeneous distribution of personality types within studies yet opposite between studies seems rather unlikely. We tried to make sure that smokers for both studies were invited from the exact same population. In addition, changes in emotional states or relevance of the pictures might also not fully explain the difference in the results. The moderators should have had an equally strong impact on the data of Study 1, which would have made the observed result of strong evidence for H_1 almost impossible. Rather we think that a more lawful mechanism could be responsible for the effect changes. We will elaborate on this idea in the following sections.

The raw data of both studies are available at the Open Science Framework (OSF): https://osf.io/4fzq8.

Overall Analyses of Study 1 and Study 2

In a final set of analyses, we included all data from Study 1 and Study 2 into one dataset to document the overall *BF* scores and the overall sequential

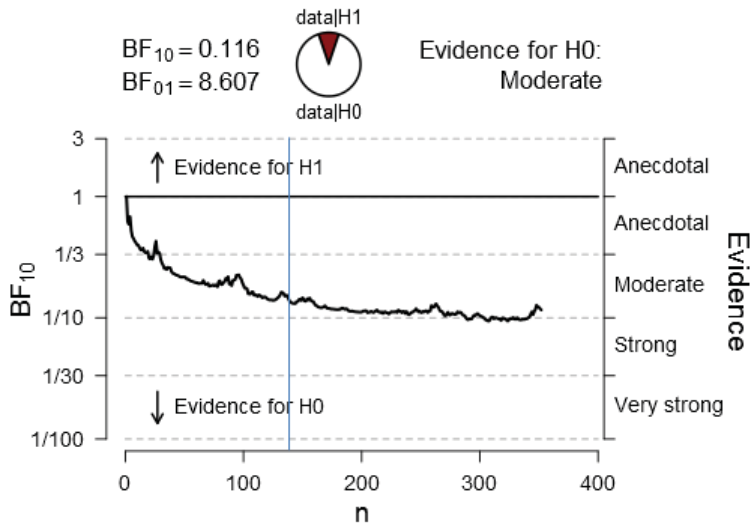

Figure 7. The curve displayed within the graph indicates the temporal change in BF when additional non-smokers were tested, i.e. when more and more evidence was included in the analysis. The transition from Study 1 to Study 2 is indicated by a vertical line at *n* = 132.

analyses. Data from identical experiments can be included in one analysis within Bayesian statistics, since this approach evaluates the accumulative evidence for or against an effect. All parameters were the same as in the studies reported above. For all following analyses, a two-tailed approach was applied.

Smokers Combined from Study 1 and Study 2

A Bayesian *t*-test with 297 smokers yielded a *BF* of 1.19 for H_1. The mean score of cigarette pictures for these participants was $M = 198.8$, $SD = 10.31$, indicating no evidence for either H_1 or H_0. The graph before the previous graph documents a sequential analysis of the Bayes factor for smokers (see Figure 6).

Non-Smokers Combined from Study 1 and Study 2

A Bayesian *t*-test with 352 non-smokers yielded a *BF* of 8.61 for H_0. The mean score of cigarette pictures for these participants was $M = 199.6$, $SD = 10.11$, indicating moderate evidence for H_0.[3] The graph above represents the sequential analysis of the Bayes factor for non-smokers (see Figure 7).

Discussion of Both Studies

An obvious detail when comparing both graphs of the overall analyses is that there was a strong change in effect across time (= additional participants) within the smokers' data, but no such change appeared within the non-smokers' dataset. One could argue that the temporal change of effect observed in smokers is just a random fluctuation. We therefore conducted a simulation run in which the experiment was executed without any observing participants.

For the simulation, one of the computers was equipped with mouse-recording software. This software handled the experimental software by itself in the same way the participants did. To get comparable results to our combined smokers' data, it was set to run until $n = 297$ datasets were collected. A Bayesian *t*-test showed a *BF* of 6.65 in favor of H_0 (M = 200.6; *SD* = 10.06). As can be seen from the sequential analysis in the graph below, no strong change appeared in the data over time. Development of the effect and final result rather resemble those of the non-smoking group (see Figure 8).

General Discussion

Our goal in the two studies presented here was to test micro-psychokinetic effects of unconsciously rooted desires during the observation of quantum experimental outcomes. Smokers and non-smoker participants were told to look at pictures that were randomly chosen by a true random number generator at each trial. Pictures with neutral or cigarette-related content each had a 50% chance of appearance. Before observation, both picture types were supposed to exist in a superposition. Through the act of measurement, the observer's unconscious mind was assumed to select the one of the two states with a slightly higher likelihood that best fits their unconscious desires. We focused on unconsciously rooted intentional states of the observers rather than on conscious intentions, since the theoretical models from which our hypothesis was derived postulate a desire-driven non-random emergence of classical states and their conscious perception out of the realm of the unconscious (see, e.g., Atmanspacher, Römer, & Walach 2002, Mensky 2013, Penrose & Hameroff 2011). Thus, mental activity originating from an observer's unconscious was assumed to causally affect motive-driven biases from randomness. In two studies, we tested the hypotheses that an observer's unconsciously rooted desire toward cigarettes should affect the tRNG's quantum probabilities for cigarette picture presentations. In Study 1 the mean score of cigarette pictures obtained with smokers was predicted to deviate from chance (two-tailed approach). In Study 2 a deviation lower than chance was expected (one-tailed approach). Null effects were expected for non-smokers.

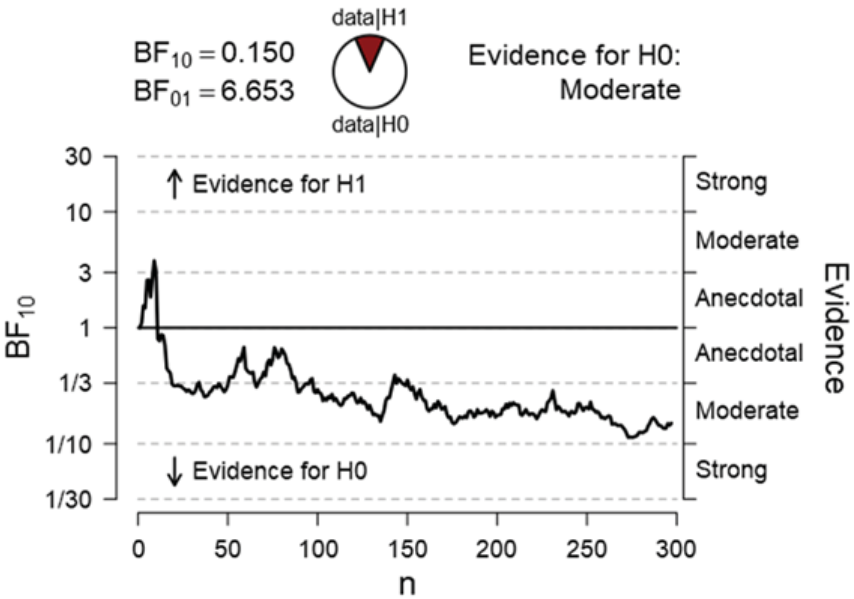

Figure 8. The curve displayed within the graph indicates the temporal change in BF when additional simulated participants were created, i.e. when more and more evidence was included in the analysis.

The results were rather mixed. In Study 1 strong evidence for H_1 was found, indicating that on average smokers observed fewer cigarette pictures than expected by chance. No deviations from chance were found with non-smokers. This is in line with the revised quantum models described above that also allow for observer-dependent deviations from randomness. The results also match with the prediction of the emotional transgression model: If the unconscious mind of the observer of smokers is convinced of not having had enough cigarettes yet, it will bias the random selection toward a lower likelihood for cigarette pictures. Thus, the unconscious belief and the established reality coincide similarly to a self-fulfilling prophecy. Subjectivity of smokers turns into objectivity here.

In Study 2, a pre-registered replication attempt, strong evidence for H_0 was found within the smoker group. This was unpredicted and surprising since a BF_{10} of 66.67 found in Study 1 was considered to provide a high likelihood for replication success, and the earlier effect could not easily be attributed to a chance finding of an underpowered sample. The overall analysis which included the data from all the smokers tested in both studies illustrated the temporal change of effect from initial appearance to later

complete disappearance. Non-smokers in both studies and in the overall analysis as well as a simulation that contained no human interaction at all showed moderate to strong evidence for no deviations from randomness. No remarkable changes in evidence for H_1 to H_0 in the course of the experiment were detected in this subgroup and the simulation data. As expected, with increasing data accumulation a smooth trend toward strong evidence for H_0 was found.

How can this data pattern be interpreted? According to the standards of scientific practice, an unequivocal replication failure indicates that there is no robust micro-psychokinesis effect in this data. Thus, the randomness postulate of quantum mechanics remains intact. This also casts doubt on the validity of the revised quantum theories presented by Atmanspacher, Römer, & Walach (2002), Mensky (2013), and Penrose and Hameroff (2011). 'No replication—game over' is what the data are saying.

Common sense would recommend accepting this as the ultimate answer to our research efforts. However, there are some indications both from other research findings as well as within our data that urge us to speculate a bit more about the existence of micro-Pk reported here despite the lack of replication. There are similar reports of replication failures of originally strong effects. One famous example is the huge micro-Pk study conducted by the PEAR group (Jahn et al., 1987) that could not be replicated by an independent research team (IGGP Freiburg and CPBM at the University of Giessen reported in Jahn et al. 2000). Parallel to this case many others have reported decline effects despite originally strong evidence (see Radin 2006). This led to speculations about moderators but also to the development of theoretical models trying to understand such decline effects. The most elaborate one was proposed by von Lucadou (2006, 2015) and is based on the idea of Pragmatic Information. According to this proposal, quantum effects such as micro-psychokinesis that violate the "no-signal theorem" should vanish when additional data are collected. The initial novelty of a study should reciprocally be related to the likelihood of later confirmation. The stronger the observed violation was, the quicker the effect would disappear during replication efforts. This would exactly match our dataset whereby an initial occurrence suddenly changes with additional data collection to a disappearance of the effect. This temporal variation was neither observed in the data obtained with non-smokers nor in the simulation where null effects were obtained throughout the data collection. This difference is striking and supports von Lucadou's (2006, 2015) assumption, admittedly on a post-hoc basis only.

The theoretical problem with this approach, however, is that real null effects documented by replication failures of spurious findings cannot

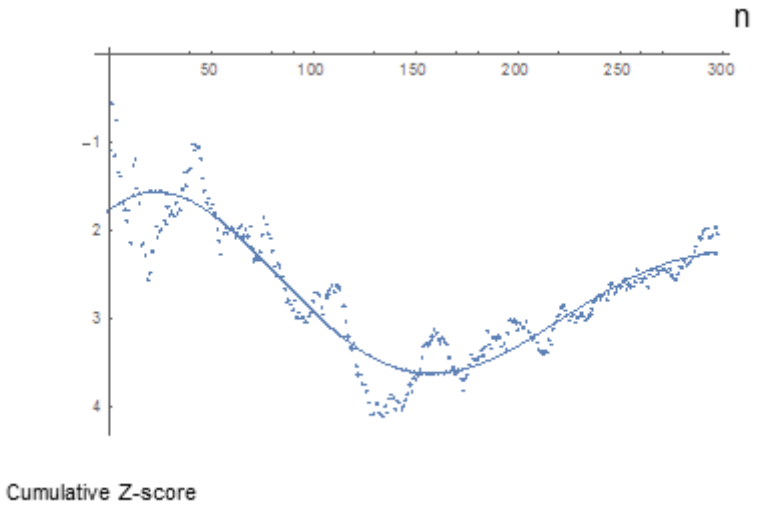

Figure 9. Cumulated Z-Score of the effect (z-transformed cumulative average score for cigarette pictures for smokers) with curve-fitting.

be distinguished from decline effects. The consequence is that with the standard scientific replication approach micro-psychokinesis effects cannot be scientifically studied. Either way, this would mean we should abandon PSI research from science (for a similar argument, see Etzold 2004).

Nevertheless, we suggest a way out of this dead-end situation. Going a bit beyond von Lucadou's (2006, 2015) Model of Pragmatic Information, we speculate that maybe the lowered confirmation trend follows a systematic pattern. A violation of the no-signal theorem in quantum physics constitutes a severe violation of the Second Law of Thermodynamics that states that entropy needs to increase over time. Hence, we assume that at the moment of the occurrence of mentally-induced deviations from quantum randomness entropy sets in to counteract this trend. Once the effect has weakened, the entropic counterforce also decreases allowing the effect to reappear although with a lowered effect size than initially shown; this interplay between effect and entropy should lead to a temporal change in effect comparable to a dampened harmonic oscillation. We estimated a mathematical function describing such a harmonic oscillation with our smokers' data (see Figure 9).

The function displayed in the Figure 9 graph was obtained with curve-fitting algorithms using the mathematical software tool Wolfram Mathematica Version 11.1.1.0 (https://www.wolfram.com/mathematica/):

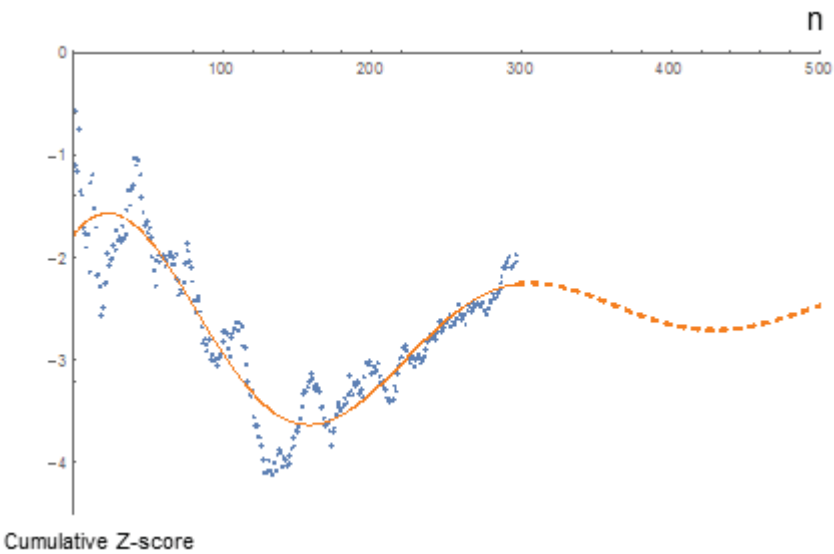

Figure 10. Cumulative time z-score of the effect (z-transformed cumulative average score for cigarette pictures for smokers) with curve-fitting and extrapolation (dotted line) to 500 subjects.

$$y = -1.650641811645734\, e^{-0.004549840402099492t} \cos(0.022532398160298193t + 2.457511536269481) + 0.001334214058230525t - 3.064904989339309$$

with y representing the effect (negative scores indicate a cumulative average score below chance) and t representing the participants in temporal order of data collection.

The prediction derived from this function would be that within the next not-yet–tested 200 smokers the effect should reappear to a lower degree in effect size and further slightly oscillate down toward the zero line. Our trend prediction can be inferred from the dotted line (Figure 10) which is an extrapolation of the accumulated effect when additional data are collected. The local maximum for this additional data should occur around subject number 410 to 450. The exact z-score for the maximum might be around −2 to −3 but could also be lower due to a further decline trend which is actually not present in the estimated part of the graph.

Our research group is currently working on similar trend estimations with other datasets, and up to now this approach seems promising. However, at present we admit that this idea of a *systematic* decay of a micro-Pk effect supplementing von Lucadou's model is highly speculative, and the goal here is just to inform other research groups about our findings and to

encourage them to re-analyze their data with harmonic oscillation functions of this kind:

$$y(t) = \alpha e^{-\beta t} \cos(\omega t + \varphi) + mt + h$$

Future research will show whether systematic decline effects can be documented and thus whether micro-psychokinesis can still be studied scientifically or not.

In addition, an alternative explanation for this null effect in Study 2 or for the oscillating pattern might also be found in experimenter effects on micro-Pk that are specifically tied to the Bayesian approach. Bayesian sequential analysis requires a continuous observation of the evidence for or against the effect. The experimenter might unconsciously affect the evidence through his expectations. In Study 1 the experimenter might have been confident about finding the expected effect, but in Study 2 due to the preregistration he might have been fearing and thus anticipating a failure. In other words the experimenter himself could evoke an oscillating micro-Pk effect on the data fully explaining the decline effect found. Such experimenter effects are discussed in Pk research (e.g., Varvoglis & Bancel 2015), and suggestions to avoid them should be taken seriously. We are not sure whether this would fully explain the non-existence of the effect in Study 2 or its oscillation, but in future research an "experimentally and theoretically blind" data analyst or an automatic analysis procedure that simply indicates when the stopping criterion is met would be recommended. For now the conclusion about the results of our studies is: There is no evidence for micro-Pk, but . . . !

Notes

[1] To gain a deeper understanding of the null effect (H_0) within the non-smokers' group, separate analyses were conducted on different subgroups of non-smokers. As can be seen from the results for casual smokers (n = 34, M = 200.7, SD = 9.33, BF = .27), former smokers (n = 12, M = 201.1, SD = 8.94, BF = .40), strict non-smokers (n = 82, M = 200.5, SD = 10.16, BF = .19), smokers of other tobacco products (n = 4, M = 197.3, SD = 6.55, BF = .65), as well as a more conservative non-smokers group consisting of strict non-smokers and former smokers who stopped smoking for at least 1 year (n = 93, M = 200.77, SD = 10.0, BF = .19), no unusual differences were found, indicating that our addiction-related stimuli did not produce an effect and these groups can be combined.

[2] Analyses for subgroups of the non-smoking sample were conducted for casual smokers (n = 36, M = 198.7, SD = 8.88, BF = .34), strict non-smokers (n = 137, M = 199.8, SD = 10.60, BF = .14), smokers of other tobacco products

(n = 9, M = 201.6, SD = 8.02, BF = .47) and the conservative non-smokers group (n = 168, M = 199.0, SD = 10.74, BF = .28). Former smokers showed a moderate deviation from the expected mean (n = 38, M = 195.6, SD = 10.74, BF = 3.33).

[3] Regarding the subgroups, a slightly different result was only found for former smokers (n = 50, M = 196.9, SD = 10.52, BF = 1.39).

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Appendix: Correlational Analyses

TABLE 1
Correlations between Mean Score of Cigarette Pictures, Positive Attitude Toward Smoking (Attitude), and Addiction Score on the Fagerström Test for Nicotine Dependencies (Fager_Score) for Study 1

		CP	Attitude	Fager_Score
Cigarette Pictures	Pearson's r	—		
	BF_{10}	—		
Attitude	Pearson's r	−0.062	—	
	BF_{10}	0.142	—	
Fager_Score	Pearson's r	−0.030	0.010	—
	BF_{10}	0.119	0.114	—

TABLE 2
Correlations between Mean Score of Cigarette Pictures, Attitude Toward Smoking, and Level of Addiction for Study 2

		CP	Attitude	Fager_Score
Cigarette Pictures	Pearson's r	—		
	BF_{10}	—		
Attitude	Pearson's r	0.184	—	
	BF_{10}	1.821	—	
Fager_Score	Pearson's r	0.018	0.079	—
	BF_{10}	0.097	0.162	—

TABLE 3
Correlations between Mean Score of Cigarette Pictures, Attitude Toward Smoking, and Level of Addiction for Both Studies Combined

		CP	Attitude	Fager_Score
Cigarette Pictures	Pearson's R	—		
	BF_{10}	—		
Attitude	Pearson's R	0.123	—	
	BF_{10}	0.681	—	
Fager_Score	Pearson's R	0.005	0.059	—
	BF_{10}	0.073	0.121	—