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<th>Title</th>
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</tr>
</thead>
<tbody>
<tr>
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</tr>
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The Power of Now: Brief Mindfulness Induction Led to Increased Randomness of Clicking Sequence

Ying Hwa Kee, Iti Chaturvedi, Chee Keng John Wang, and Lung Hung Chen

The capacity for random movement production is known to be limited in humans (e.g., Newell, Deutsch, & Morrison, 2000). We examined the effects of a brief mindfulness induction on random movement production because there are useful implications for variability in solving movement-related problems. The main task involved randomly clicking the 9 boxes in a 3 × 3 grid presented on a computer screen for five minutes. We characterized the sequence of clicking in terms of degrees of randomness, or periodicity, based on the fit, or probability, of the experimental data with its best fitting Bayesian network (4-click memory nodes) using the Markov chain Monte Carlo (MCMC) approach. Sixty-three participants were randomly assigned to either the experimental or the control condition. Mixed design repeated-measures ANOVA results show that the short mindfulness induction had a positive effect on the randomness of the sequence subsequently produced. This finding suggests that mindfulness may be a suitable strategy for increasing random movement behavior.

Keywords: creativity, present-moment awareness, action, stochastic, Bayesian network.

Humans are creatures of habit. It has been documented that humans’ capacity for generating randomness is somewhat limited (e.g., Reichenbach, as cited in Wagenaar, 1972). This limitation may be due to factors associated with functional and/or physical constraints inherent in the human biological system. A functional factor previously proposed is the limitation of the retrieval of short-term memory (Wagenaar, 1972), which causes behavior to be predictable because the most recent behavior tends to be remembered and repeated. Factors associated with physical constraints within the movement system could also limit the explorations of degrees of freedom, thereby restricting random movement production (Newell, Deutsch, & Morrison, 2000). However, given that there are advantages associated with

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self-generation of random behavior, such as, from the evolutionary standpoint, the variability of strategies and creativity during problem-solving (e.g., Campbell, 1960; Glimcher, 2005; Simonton, 1999), there has been considerable interest in the topic of humans’ capacity to generate randomness (e.g., Figurska, Stańczyk, & Kulesza, 2008; Persaud, 2005; Schulz, Schmalbach, Brugger, & Witt, 2012).

Our interest in random movement production was motivated by the idea that reinforced variability may facilitate the learning of new responses, creativity, and problem solving ability (Neuringer, 2004). Given the potential benefits of self-generated variability to the enhancement of problem-solving in motor control, we examined the effects of our brief mindfulness manipulation—primarily focusing on breathing mindfully—on random movement production. Specifically, we examined the effects of mindfulness on the generation of a random clicking sequence in a motor-based computer task. We postulated that if momentarily applying mindful attention could improve the generation of random movements, mindfulness may serve to enhance problem-solving in motor control and learning endeavors.

The facilitative role of variability in the context of motor control has been widely studied (e.g., Arutyunyan, Gurfinkel, & Mirskii, 1968; Carlton, Chow, & Shim, 2006; Davids, Button, & Bennett, 2008; Stergiou, Harborne, Cavanaugh, 2006). For example, Carlton et al. cited evidence of seeded tennis players in the 1996 Olympics producing first serves with highly varied racquet speeds and found that variability in racquet speed is associated with high ball velocity. Arutyunyan et al. reported that expert pistol shooters produced greater joint movements while aiming, resulting in the reduction of spatial variability of the pistol barrel. Davids et al. also suggest that higher variability in the initiation phase of movements in a dynamic sport such as table tennis allows skilled players to select a shot from a wider repertoire of strokes, as evidenced by the study reported by Bootsma and van Wieringen (1990). In summary, variability is ubiquitous in the movement system, and its natural occurrence has been viewed as facilitative in some incidences.

Movement variability can be facilitated by external agents such as a coach or a physical educator. For example, the implementation of variable practice and contextual interference (e.g., Magill & Hall, 1990), aimed at exposing learners to different learning conditions and drills, are strategies normally adopted by practitioners to increase movement variability during practice. When such strategies are administered, learners are made to vary their existing movement repertoires to explore new movement patterns with the ultimate goal of learning the prescribed skills. In practices which use the constraints-led approach that is grounded in the dynamical systems perspective, when “learners get stuck in a rut” (as in a plateauing effect) during the acquisition of motor skills, instructors can help learners move away from the existing attractor and direct them toward the desired movement pattern by purposefully inducing movement pattern variability with a change of practice drills (Davids et al., 2008). For example, in tennis practice, a learner’s movement variability can be facilitated by altering the flight characteristics of balls fed to them or by asking the learner to hold an additional ball or racket in the nondominant hand while practicing the task. In both cases, the learner may perceive such practice drills to be experientially different from their recently performed drills. As they perform drills that they are not used to, it is expected that there will be a temporary increase in errors and variability in movements, but the exaggerated departure from usual movement repertoires are deemed important for
the acquisition of new movement patterns in some circumstances, as exploration of perceptual-motor landscape takes place (Davids et al., 2008).

In the case above, it is normally the coach or teacher who institutes the increase of movement variability to facilitate learning. However, when learners practice on their own outside the formal practice setting, they will have to implement strategies on their own to increase movement variability to get themselves out of the “rut.” Given that self-controlled practice is not uncommon, and its benefits have been well-documented (e.g., Wulf & Toole, 1999), learners’ ability to vary their own practice when they are not progressing can be critical for eventual successful learning. While variability is not synonymous with randomness, we postulate that efforts to increase randomness in movement can certainly raise the level of movement variability to an optimal level in cases where variability is desired. Furthermore, we are particularly interested in the human capacity to generate random movements because intentionally modifying movements from trial-to-trial in a seemingly random fashion has been reported to have some value for skills acquisition, as outlined in the differential learning approach proposed by Schöllhorn (1999).

Briefly, in the differential learning approach, learners are asked by the coach to execute all their given practice trials differently by modifying some parts of the action while keeping the core movement intact. As an illustration, a soccer coach adopting this approach could instruct the player to perform the first kicking trial by placing his right hand behind his head throughout the trial, then in the second trial to put his left arm across his chest, and continually changing some parts of the action for all remaining trials. The essence of this approach is that no trials are repeated in the same way, and the varied additions to the movements between trials are randomly assigned by the coach. Previous studies suggest that the effects of the differential learning approach are promising (e.g., Savelsbergh, Kamper, Rabius, De Koning, & Schöllhorn, 2010; Schöllhorn, Michelbrink, Welminsiki, & Davids, 2009), given that there is greater exploration of the perceptual motor workspace due to increased perturbations to the movement system via this approach. If a learner is to adopt the differential learning approach or to introduce movement variability in a self-learning situation, the ability to select or generate random actions at will during practice would be important. The capacity for self-institution of random movements or movement variability could potentially enhance the searching strategies learners apply to the perceptual-motor workplace as they try to solve the degrees of freedom problems in coordinating movements. In addition, in terms of enhancing sport performance, the capacity to self-generate random moves during the game can also tactically surprise the opponent, and in so doing, the athlete can gain an advantage.

Humans are, however, not adept at producing or learning to produce random movements. An earlier study by Newell et al. (2000) showed that the degree of randomness in a finger flexion and extension movement task could not be significantly increased despite five days of practice, even with the availability of feedback. They argued that there are tight constraints on the number of dimensions regulating single limb planar motion that are not easily changed by traditional practice protocol, which is a case of physical constraints limiting the production of randomness. In cases where such physical constraints dominate, an alternative is to overcome the effects of physical limitations through psychological techniques. To this end,
Neuringer (2004) suggested that increased attention during the task may improve randomness generation, citing evidence from several sources (Baddeley, Emslie, Kolodny, & Duncan 1998; Evans & Graham, 1980), which showed that divided attention undermines the approximation of random sequence. In addition, Neuringer (2004) cited Langer’s interpretation of mindfulness grounded in attention toward one’s activity as a way of increasing functional variations.

In the current study, we examined Neuringer’s (2004) speculation further by examining the effects of a psychological quality associated with attention—mindfulness, which can be loosely defined as moment-to-moment attention and awareness (Kabat-Zinn, 1990)—on the subsequent performance of a computer-based random clicking task. Mindfulness can be practiced as a psychological skill (Baer, 2003), say, simply by paying attention to one’s breathing repetitively, or by paying attention to one’s movement. This construct has received considerable interest in the field of psychology in the last decade (Andersen & Mannion, 2011), and it is widely conceived as a positive psychological construct associated with performance enhancement (e.g., Gardner & Moore, 2004; Kee & Wang, 2008) and well-being (e.g., Shapiro, Oman, Thoresen, Plante, & Flinders, 2008). Since mindfulness can be construed as a state of focus on ongoing situations in a nonjudgmental fashion, the relevance of this construct for randomness production lies in its association with orientation toward openness (Bishop et al., 2004), a quality that may predispose individuals toward producing novel alternatives. While there is virtually no previous study on the links between mindfulness and random movement production, a recent study on postural control by Kee, Chatzisarantis, Kong, Chow, and Chen (2012) found that participants with stronger mindfulness dispositions benefited from a brief mindfulness manipulation, showing a greater increase in the complexity of medio-lateral center-of-pressure movement profile. Since greater complexity corresponds to a higher degree of randomness, we speculate that the effect of mindfulness induction might translate to an increased production of random movements in a task with a tight degree of freedom. Although the target movement used here was a simple computer-based task, we reasoned that such a task with a limited degree of freedom, while allowing ease of data collection and analysis of movement sequence, is a suitable starting point for the examination of the effects of a brief mindfulness induction on random movement production.

In summary, we examined whether our brief mindfulness induction increased randomness in the clicking sequence of our target task. We hypothesized that randomness in movements, normally difficult to produce, can be increased significantly through a brief bout of mindfulness induction.

**Method**

**Participants**

Sixty-three right-handed male university students ($n = 35, M = 22.9$ years old, $SD = 1.36$) and female university students ($n = 28, M = 21.6$ years old, $SD = 0.73$) participated in this study. They provided informed consent and were paid a token sum of approximately US$3 for their involvement. Approval was granted by the Institutional Review Board for the conduction of this study.
Instruments

**State Version of the Mindful Attention Awareness Scale (MAAS-State: Brown & Ryan, 2003).** The 5-item MAAS-State version questionnaire was used as a manipulation check instrument for ascertaining the level of state mindfulness after manipulation. The items assess the degree of mindful attention and awareness at the time of signal. A sample item reads: “I was doing something without paying attention.” Participants were asked to rate the questionnaire items using a Likert scale of 0 (not at all) to 6 (very much) according to what they had recently experienced. A lower mean rating derived from all five items denotes a higher state mindfulness level. The MAAS-State is known to have excellent psychometric properties (e.g., Cronbach’s $\alpha = .92$; Brown & Ryan, 2003).

Tasks

**Random Clicking Task on a 3 × 3 Grid.** The computer-based task, written using JAVA, involved participants moving a standard optical mouse cursor and clicking the 9 boxes arranged in a 3 × 3 grid on the computer screen in a random fashion continuously for 5 minutes. Participants were briefed that the aim of the task was to produce as much randomness as possible as they clicked the boxes within the grid. They were told that a measure of the randomness in the sequence of their clicks would be calculated for the purpose of research. No feedback on their degree of randomness was provided to the participant during the experiment. The cell location of every click during the trial was recorded for subsequent analysis.

We devised and selected this task because the nature of the clicking task is in part similar to the finger planar movement task used by Newell et al. (2000), as the associated degrees of freedom on the phalangeal joint are also largely constrained since moving and clicking the optical mouse involves limited movements. A task with reasonably tight constraints such as the prescribed random clicking task renders the production of randomness more difficult and makes it a suitable task for testing the effects of our mindfulness induction.

**Mindfulness Induction and Control Condition.** In the mindfulness condition, participants were asked, via a standardized audio script through a pair of headsets, to place the index finger under the nostril and specifically “to pay attention to the sensation on your finger as you breathe in and out normally” before the start of the 6-min mindfulness induction period. In addition, they were shown the image of the required hand position and were also told that a series of audio bell chimes will be played periodically as a reminder for them to be mindful of sensation of their fingers. In the control condition, participants were also instructed via an audio headset before the start of the 6-min period to place the finger under the nostril. They too were shown the image of the required hand position and were told that several audio bell chimes would be heard, but they did not receive any instruction to be mindful of their breathing. For both conditions, the bell chimes were scheduled to sound at the start of the 6-min period and repeated at 1-min intervals till the end. For the control condition, these chimes were meant to be meaningless; and for the mindfulness induction group, these chimes served as reminders to the participants to be mindful of their breath.
Procedures

After providing informed consent, participants were asked to perform the random clicking task once as the pretest. They were then randomly assigned to either the mindfulness induction or control condition. The manipulation check questionnaire was administered via a computer-based survey program immediately after the 6-min manipulation period. Following the survey, participants performed the random clicking task again as the posttest. They were debriefed on the goal of study at the end.

Data Reduction and Analysis

**Measure of Randomness.** To quantify the production of random movements as the dependent variable, we characterized the sequence of clicking in terms of degrees of randomness, or periodicity, with the fit, or probability, of the experimental data with its best fitting network (based on 4-click memory nodes) using the MCMC approach. In summary, the entire procedure can be explained in three main stages: preparing the data, modeling data of four consecutive clicks as Bayesian networks, and deriving fit indices based on MCMC simulations.

In the first stage, we standardized the length of clicking data and defined each data sequence as a 9-dimensional multinomial sequence. As the number of clicks varies between individuals and between trials for each individual, and the derivation of Bayesian probability is dependent on the length of observed sequence; to compare the randomness of the pre- and posttest samples for each individual based on a common length, we based our analysis on the length of the shorter of the two samples by dropping some initial data points of the longer sequence. A single click is in effect a 9-dimensional random variable since there are 9 possibilities for each click. In turn, each click on the $3 \times 3$ grid generates a 9-dimensional multinomial distribution $m_t \in \{1, 2, \ldots, 9\}$. The clicking sequence for each trial thus becomes a 9-dimensional multinomial sequence. In short, at this stage, we standardized the length of the 9-dimensional multinomial sequence for pre- and posttests data for each participant before further analysis.

In the second stage, we model each sequence into its respective 4-node Bayesian networks. Each click relates to the previous click in the sequence by a first-order Markov chain which assumes that transition probabilities between clicks remain constant (Friedman, Murphy, & Russell, 1998). We extend this assumption to a third-order Markov chain where transition probabilities from any of the previous three clicks are considered. Since we would like to look at four consecutive clicks for repeated patterns, we used four random variables (or four clicks) to model the multinomial sequence according to Bayes’ Law. The problem can be formulated as a Bayesian network $\{c_{ij}\}_{i=1:4, j=1:4}$, where each edge corresponds to a causal relationship between click locations $i$ and $j$ in the sequence. The time-series for each random variable (single click) click node $m_t$ is thus a subsequence $\{1, 2, \ldots, T-t-1, T-t\}$ in the original sequence of length $T$ clicks. This results in a Bayesian network of four random variables, a directed acyclic graph of four nodes representing an independent random sequence of clicks. Any structured information embedded in a periodic or chaotic clicking sequence is reflected in a certain predicted network by the Bayesian model. Figure 1 shows a possible Bayesian network connecting four consecutive clicks.
In the third stage, we used the maximum-likelihood estimation method to derive fit indices as the measure of sequence randomness, by fitting the original sequence to its best fitting structure obtained through the Markov chain Monte Carlo (MCMC) simulation. The best fitting structure is used as the model for the most repeated 4-node sequence within the series of clicks, and had to be detected before ascertaining the probability of it being repeated within its original sequence. If the probability is high, the randomness of the clicking sequence is low, given the predictability. We ascertain this probability as an index of randomness through a fit index, generated by fitting the best fitting structure with the original data. The fit index, specifically known as the maximum-likelihood estimate (ML), is a probability measure where a lower probability value represents greater randomness (Friedman, Murphy & Russell, 1998). The probability values range from negative infinity, or log 0, for perfectly random sequence, to zero, or log 1, for a perfectly periodic sequence. In effect, we undertook a process to fit the 9-dimensional multinomial sequence (defined in the first stage) into the 4-node Bayesian network (defined in the second stage), with the aim of finding the best fitting structure connecting the four nodes for each trial, which will also produce the highest corresponding ML. The ML of each trial/sequence’s best fitting structure can then be used as the randomness measure for comparing clicking samples between conditions, since it is a measure of extent of nonstationarity or randomness of clicking sequence. As an illustration of how the randomness of sequence is quantified, consider two

**Figure 1** — A Bayesian network of four-click nodes at time $t_1$ to $t_4$. The connectivity matrix depicts the possible sequence of pattern in the clicking time series.
clicking sequences: A which is 1–2-3–4-1–2-3–4-1–2-3–4 (more periodic), and B which is 5–2-1–3-2–4-3–4-1–3-2–4 (less periodic). The best fitting sequence for A (derived from the MCMC) would be 1–2-3–4 because this is the most probable repeating pattern within this sequence (appearing thrice); and for sequence B, it will be 1–3-2–4 (appearing twice). In deriving the ML or fit index, when the clicking sequence is compared with its best fitting sequence, we can determine the probability of the fit based on ML. Given that the probability of 1–2-3–4 finding similarities in sequence A is higher than that of the probability of 1–3-2–4 finding similarities in sequence B; the ML for the sequence A is higher than sequence B, signifying that sequence A is less random than B. In short, the value of ML is inversely proportional to randomness.

A brute-force search for the best fitting structure is, however, not possible, since the number of possible directed graphs is exponential in relation to the number of nodes given by $2^{(n(n-1))}$, where n is the number of nodes. In addition, the integral over parameters becomes intractable with the ML method. Therefore, we performed a global search for optimal structure using MCMC simulations. In the simulation, we begin with a random starting structure in the form of a 4-node Bayesian network, and calculated the ML or the fit of the 4-node clicking sequences with this simulated Bayesian network (which also follows a multinomial distribution, and is uni-modal with single global maxima). The fit is likely to be poor, characterized by low ML, since the starting structure was formed randomly; and more iteration is needed to find the best fitting structure. Since the fit is unsatisfactory, the next step is to propose a new network structure by applying one of the elementary operations to the structure, such as deleting, reversing, or adding an edge. A sampled structure is accepted if the ML of the corresponding Bayesian network is higher than the previous structure in the chain. A binomial prior for number of edges for each node ensured that a reasonable structure was predicted. Sampling continues until convergence or when ML of the chain does not improve any further. Lastly, to accurately integrate out the parameters, an average over sampled structures with similar probabilities after convergence is taken to form the best-fit structure. The averaged probabilities is then adopted as the ML, or the fitting index of the 4-node clicking sequence with respect to the best fitting 4-node Bayesian network.

**Statistical Analyses**

Descriptive statistics were calculated for the mean number of clicks made by each participant. The most and least popular choice of position within the grid was also ascertained. To examine effects of manipulation, an independent-sample t test was conducted to compare MAAS-State scores in the experimental and control conditions. In the main analysis, a 2 (time: pretest vs. posttest, within variable) by 2 (condition: mindfulness induction vs. control condition, between variable) mixed design repeated-measures ANOVA was adopted. The General Linear Model (GLM) was used to examine the interaction effect on the randomness measure. Simple main effect analyses were performed to examine whether the change between the two time points are significant for the respective conditions.
Results

Descriptive Statistics

Overall, the mean number of clicks made by each participant for the pretest is 697.52 ($SD = 196.76$), and for the posttest, it is 727.75 ($SD = 205.50$). Among the boxes available in the grid, the most frequently selected position regardless of condition and phase of testing is the middle position, while the bottom left corner of the grid is the overall least popular choice. The time-series is nonstationary as frequency of clicking and the sequence clicked varied with time; given that the goal of the task is to produce randomness, and all participants adhered to the instruction to the best of their ability.

Manipulation Check

MAAS-State scores for the experimental group are significantly lower ($M = 3.59$, $SD = 1.14$) than those of the control group ($M = 4.39$, $SD = 0.96$) conditions; $t(61) = 2.97$, $p = .004$, $d = 0.76$. The results suggest that the participants who underwent the mindfulness induction reported higher levels of state mindfulness as was expected.

Mixed Design Repeated-Measures ANOVA

The dependent variable, randomness measure, used for quantifying randomness in each clicking sequence is based on the ML—the fit index representing the fit between 4-node clicking sequences and the best fitting 4-node Bayesian network. A lower ML or fit index corresponds to greater randomness. Results show that there is a significant interaction between time and condition in the randomness measure [$F(1, 61) = 5.62$, $p = .021$, $\eta_p^2 = .084$]. Specifically, results from the simple main effect analyses show that participants who underwent the mindfulness induction produced significantly higher randomness (lower ML) at the posttest with reference to their pretest results [$t (1, 31) = 2.21$, $p = .035$, $r = .37$], while the change in the control group’s production of randomness was nonsignificant over time [$t (1, 30) = -1.09$, $p = .284$, $r = .20$]. Table 1 shows the means and $SD$ of the respective cells in this analysis. Figure 2 illustrates the interaction effect.

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<thead>
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<th>Table 1</th>
<th>Comparisons of Randomness Measures (based on ML) for Different Conditions Across Time</th>
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<tr>
<td><strong>Mindfulness Induction ($n = 32$)</strong></td>
<td><strong>Pretest $M$ ($SD$)</strong></td>
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<tr>
<td>-4800.77$_a$</td>
<td>-4842.15$_b$</td>
</tr>
<tr>
<td>(1376.22)</td>
<td>(1405.28)</td>
</tr>
<tr>
<td><strong>Control ($n = 31$)</strong></td>
<td>-4884.24</td>
</tr>
<tr>
<td>(1389.56)</td>
<td>(1410.09)</td>
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Note. Differing subscripts denote significant difference findings at $p < .05$. A lower ML value represents lower fit of the clicking sequence with the best fitting Bayesian network of four-click memory nodes, and corresponds to greater randomness in the sequence produced.
In this study, we examined the effects of a brief mindfulness induction on the production of random movements during a computer-based clicking task. The significant between-group differences in the manipulation check measure observed based on the MAAS-State questionnaire suggest that our mindfulness induction is valid. The mixed design repeated-measures ANOVA result shows that our mindfulness manipulation, based on momentary attention to one’s breath, corresponded to higher randomness in the clicking sequence compared with the control condition. This finding suggests that the participants’ efforts in increasing movement randomness within a short timeframe had been facilitated by the aftereffects of our mindfulness induction.

We can interpret our findings in light of ideas from the dynamical systems approach, which is a well-accepted approach in the field of motor behavior (e.g., Newell, Liu, & Mayer-Kress, 2003). Metaphorically, we may consider the collection of separate clicking behaviors as discrete states joining up to form a trajectory occupying the n-dimensional state space of the dynamical system in question (Vallacher & Nowak, 1997). If the trajectory returns to the same neighborhood periodically, it means that the states are repeated periodically and that a stable behavior is present. In the language used to describe complex systems, such a pattern signifies an attractor that is not easily perturbed. When asked to perform a task in which the goal is to create randomness, the challenge for the participant is to overcome the compelling tendencies of repeating actions recently performed, since the most recent
patterns are likely to get repeated due to the immediacy of memory (Wagenaar, 1972). The repetition of a particular clicking behavior produces an attractor that is stable, and there are strong intrinsic dynamics for such behavior to recur in the near future. Since the strength of the attractor can be ascertained by introducing a perturbation to the system, the mindfulness induction administered between the pretest and posttest can be conceptualized as the perturbation we introduced to the system in attempt to weaken the tendencies of repeating sequences of clicks (or attractor). In contrast, we do not expect the random clicking behavior to change considerably in the absence of an effective perturbation, such as in the case of the control group. As the pre- to posttest differences observed among participants in the control group were nonsignificant, the result suggests that the randomness produced did not change considerably even with a brief break in between the pre- and post-tests. We can infer that, under normal circumstances, the intrinsic dynamics of clicking in a particular pattern will be present despite efforts to be random.

Given that our mindfulness induction resulted in a higher MAAS-State score than the control group in the manipulation check, we now turn our attention to the effects and potential benefits of the mindfulness induction. Results from the mixed design repeated-measures ANOVA show that our mindfulness induction perturbed the clicking behavior between the pre- and posttest sufficiently enough to produce significant increase in the randomness of the sequences of clicks, signaled by lower ML. In other words, the brief mindfulness induction changes the trajectory of clicking patterns to one that is representative of greater unpredictability, or randomness. Discovering that a simple instruction asking participants to pay attention to breathing can improve subsequent random movement production is an important contribution of this study. This improvement in one’s capability for random movement generation, albeit perhaps transitory, via a brief mindfulness induction could be particularly important for learners or athletes who are “stuck in a rut” of a well-entrenched habitual movement pattern. Particularly, during self-controlled practice or in competitions, when the coach is not there to facilitate any required random movement or movement variability, it will be the learner who has to produce the advantageous movement variability themselves. The present findings suggest that taking a few moments to be mindful of one’s breathing could enhance the capacity for producing movement randomness. We speculate that this could in turn facilitate the explorations needed to overcome the motor problem confronted, given the functional roles of movement variability discussed earlier (e.g., Davids et al., 2008).

Assuming our mindfulness induction allowed elements of mindfulness states to be sustained during the clicking task, we speculate that the reason why mindfulness might facilitate more randomness may be due to the participants’ successful disassociation with past events. Normally, when one attempts to be as random as possible in the sequence of clicks made, comparisons are continually directed to choices made in the recent past to allow them to select a subsequent box that is different from the past. However, since there is a limit to how much one can successfully recall during a random generation task—for example, Baddeley et al. (1998) demonstrated that longer recall sequences produce less random output—trying to
remember previous sequences may not be the most effective strategy for creating random sequences. Even purposefully avoiding similar clicking patterns based on memory of previous clicks might lead to the ironic effects of poorer recall due to a heightened mental workload (Hart, Randell, & Griffith, 2007), which in turn unwittingly results in a preferential clicking sequence that lacks unpredictability.

In an effort to maximize randomness of sequence, one should click on a new cell entirely based on a random selection and not be clouded by previous actions. One should perform the clicking task as if restarting the task with every click, because, in theory, only when one is restarting the task will there be no previous states to reference, and that is the key to being truly random. Following mindfulness induction, participants may be more likely to apply this quality of what is normally known as the “beginner’s mind” (Bishop et al., 2004) because our mindfulness induction is characterized by present-moment awareness, via the strategy of paying attention to one’s breathing. By definition, present-moment awareness necessarily suspends thoughts about the past and the future. Following this argument, it seems that our mindfulness induction could have led to the suspension of previous physical habitual behavior while the posttest was performed, and thus higher randomness was resulted. This suspension of any previous experience may be somewhat similar to the idea of blind variation proposed by Campbell (1960), in which a complete lack of inference from past experience can be associated with greater creativity, and thus greater randomness.

While research has shown that mindfulness is an adaptive quality that helps curb habitual tendencies in a broad spectrum of behavior, such as binge eating (e.g., Leahey, Crowther, & Irwin, 2008), addictions in smoking (Brewer et al., 2011), and gambling (de Lisle, Dowling, & Allen, 2011), evidence for the effects of state mindfulness on motor control is still scarce. To the best of our knowledge, only two studies were published on the topic of brief mindfulness induction and motor control behavior. Djikic, Langer, and Stapleton (2008) showed that after priming participants for ageism stereotype by asking them to view and sort pictures involving elderly persons, the experimental group which underwent a brief induction of mindfulness through the increase of novelty during the sorting task resulted in a faster walking speed compared with the control condition. Their explanation is that the effects of ageism which will normally cause participants to walk slower could be suppressed because of mindfulness induction, as alternative view of the pictures were activated rather than getting fixated on ageism. In a recent study, Kee et al. (2012) also showed that a brief mindfulness manipulation increased the approximate entropy of a postural balance profile for those with higher mindfulness disposition. As approximate entropy is a measure of the complexity of the behavior, we can deduce that mindfulness may be associated with the increase of variability, or varied behavior. Based on the findings from these two studies, momentarily inducing mindfulness (albeit using slightly different approaches in different studies) seems to elicit a change in the otherwise habitual motor control tendencies. There is a need to further examine the links between mindfulness and motor control given the relevance of mindfulness in curbing habitual tendencies found in movements.
Given that our mindfulness induction is simply performed by directing participants’ attention to their breath for a brief six-minute period, and that we demonstrated that randomness can be increased significantly with it; there are two practical implications related to the enhancement of motor control arising from this key finding. First, learners experiencing a plateau while learning motor skills may benefit from a brief bout of mindfulness practice since the degree of self-instituted variability could be increased as a result. By increasing one’s variability in the movement pattern, there may be a better chance of finding solutions to the existing movement problem (Schöllhorn et al., 2009). Before a learner becomes capable of voluntarily applying mindfulness strategies, the coach or instructor could be the one providing some form of mindfulness induction to inject perturbations to the learner’s ongoing maladaptive intrinsic dynamics which are associated with unwanted repetitive habits. Secondly, in competitive sports, athletes could also consider using the simple mindfulness technique of paying attention to one’s breath momentarily to facilitate the execution of unpredictable movements to surprise their opponents. For example, in badminton, an increase in the unpredictability of shots played will make the returning of shots difficult for the opponent. Although element of surprise is particularly important for successful deception in badminton (Grice, 2007), and the intention to surprise was highlighted as one of the strategies expert badminton players could use (Macquet & Fleurance, 2007), the selection of strokes during a fast paced game is, however, often influenced by one’s habitual tendencies due to the time pressured nature of rallies, and in turn resulting in predictable plays (Grice, 2007). In this instance, the act of placing one’s finger below the nostril and paying attention to the sensation of breath momentarily before beginning a rally can be a potentially simple technique to help the player redirect his/her mind to the present moment, thereby reducing the tendencies of using recently adopted strokes and increasing the unpredictability of upcoming strokes. With further use and training of mindfulness skills, both learners and athletes may benefit from its application at will while attempting to increase the extent of randomness in their movement repertoire for adaptive reasons.

Although the mindfulness technique used in this study seems to be efficacious in altering habitual motor control, at least temporarily, two limitations associated with our study should be noted. First, since this is a study that is preliminary in nature, in which the target task was a computer-based clicking task, and was restricted to phalangeal joint movements, it is uncertain how effective our mindfulness induction will be for movements with a greater degree of freedom. Perhaps variability or random movement production in multiarticular actions can be easily facilitated by implementing task constraints, and that the positive effects of mindfulness induction would be relatively limited in comparison with implementations of effective coaching. Although the current study suggests that a brief mindfulness induction can increase randomness in a simple clicking task, more research is needed to ascertain the effects of mindfulness in the production of random movements or creativity during the practice of actual sporting actions which involve higher degrees of freedom. As the purpose of generating randomness is to improve creativity in problem solving, it may be that the effects of mindfulness strategies on creativity are weaker than that of a well-instituted instructional constraint specially geared
for the specific athletic skill. For example, the relaxation of task constraints, either
directly by asking the learner to adopt any actions that they find efficient for the
given task, or indirectly by using stringent instructional constraints to suppress
habitual action and posing questions to elicit possible solutions, could also facil-
itate learners’ creativity for solving motor problems (Hristovski, Davids, Araujo,
& Passos, 2011). However, whether mindfulness can further increase a learner’s
receptivity toward such relaxation of task constraints, and in turn allow them to
benefit more from such instructional strategies is not known. This issue is worthy
of further investigation as learning styles differs between learners, and a previous
study based on motor learning via self-controlled learning protocol by Kee and
Liu (2011) suggest that learners with stronger mindfulness dispositions enjoy self-
controlled learning situations better than less mindful learners. Some learners may
not respond to relaxation of task constraints as favorably as the others, perhaps
due to a weaker inclination to innovate. Mindfulness induction may help in such
situations. Second, since the mindfulness induction happened before the task, it
is not known whether the task itself is performed mindfully. It may be the case
that mindfulness of the movements, per se, during the task is not conducive to the
production of random movements. Previous research on attentional focus suggests
that internal focus leads to less effective motor control and greater constriction of
behavior, such as the study reported by Shea and Wulf (1999) on the link between
internal focus and the reduction of degrees of freedom in the stabliometer task.
Further research is warranted to investigate whether mindfulness during the task
facilitates random movement.

In conclusion, the current study found that a brief bout of mindfulness induc-
tion led to a greater production of random movements. This finding has important
implications for motor control and learning because the production of random move-
ments, particularly if it is for a task with limited degrees of freedom, is supposed
to be very difficult. The findings of this study, when viewed from the dynamical
systems perspective, suggest that the momentarily perturbation in the form of
becoming mindful of breath alters the trajectory of usual movement behavior to
one that involves more varied movements. The development of potential for self-
initiated variation of movements may be particularly important for overcoming
learning plateaus and producing unpredictable play in sports.

As interest in the roles of mindfulness in human performance increases,
understanding how present-moment awareness led to increased variability that is
functional for motor control will continue to be important. Extrapolating our find-
ings to the larger context of human behavior and evolutionary success, mindfulness
could be a viable strategy for promoting randomness and creativity important for
solving movement-related problems and beyond. Given that the development of
mindfulness through training over a period positively impact on neuroplasticity
(e.g., Allen et al., 2012; Moore, Gruber, Derose, & Malinowski, 2012), with our
present documentation that mindfulness can enhance greater random movement
generation behaviorally, further research at both neurological and behavioral levels,
on the roles of mindfulness strategies as a cause for more permanent change of
capacity in random movement production and creativity, is warranted. We suggest
that the implications of increasing random movements at will through mindfulness
extend beyond the domain of motor behavior, toward understanding how habitual tendencies can be curbed in other aspects of life, because virtually all human activities involve motor control.

Notes

1. To ascertain that the dropping of initial data points was inconsequential for the eventual data analysis when addressing the main research question, we performed a mixed design repeated-measures ANOVA on the data points based on the same procedure for the first minute (which was presumably the period when initial data points were dropped), and found that the outcome of the analysis is consistent with the final analysis.

2. A trial-and-error method was used to determine the optimal order of Markov chain to be adopted. The sequences were well-correlated to third order, because when the order was increased to five memory states (order four) or reduced to three memory states (order two) the sequences were no longer well-correlated as the ML which measures a fit to the data were lower and the two groups are not well-separated.

3. Perturbation normally refers to sudden and brief disturbance. Although the mindfulness manipulation period was six minutes and was in fact longer than the time taken for each random clicking task, we still considered the manipulation as a perturbation. We take the participants' performance during the experiment to be representative of their typical clicking behavior as far as random movement production is concerned. Based on the nonsignificant change in performance between the two trials in the control condition, we infer that the capacity for randomness cannot be easily changed. We assume that this inability to produce random movements was present before the experiment and will continue after the experiment. Following this argument, the six-minute manipulation can be considered as a perturbation given that the time horizon in question was much longer than the manipulation.

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