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OBSERVATION

Isolating the Perceptual From the Social: Tapping in Shared Space Results in Improved Synchrony

David W.-L. Wu
University of British Columbia

Craig S. Chapman
University of Alberta

Esther Walker
University of California, San Diego

Walter F. Bischof
University of Alberta

Alan Kingstone
University of British Columbia

Current theory suggests that interpersonal synchrony is an important social behavior in that it not only serves as a form of "social glue," but it also arises automatically in a social context. Theorists suggest potential mechanisms for interpersonal synchrony, ranging from a "low-level" social–perceptual system account to a "high-level" social–motivational explanation. Past studies that suggest synchrony can be influenced by social factors do not discriminate between these accounts. The current investigation seeks to isolate the effect of the high-level social system on interpersonal synchrony by investigating the effects of spatial proximity on unintentional coordinated tapping between two naïve participants. Dyads performed a synchronization-continuation task either in the same room, in different rooms, or in different rooms but with the ability to hear each other tap. Participant taps were represented by a box that flashed on the monitor to control visual information across all three conditions. Same-room dyads had increased coordination over different-room dyads, whereas dyads that shared audio but were in different rooms showed an intermediate level of coordination. The present study demonstrates that shared space, independent of perceptual differences in stimuli, can increase unintentional coordinated tapping.

Keywords: rhythm, social cognition, interpersonal synchrony, coordination dynamics, psychological distance

Recent interest in interpersonal synchrony—how people perceive and follow external rhythms from others in social situations—has grown immensely as theories suggest that such behavior serves as a form of "social glue" (Kirschner & Tomasello, 2009; Marsh, Richardson & Schmidt, 2009). Studies have consistently found that dyads often spontaneously and automatically synchronize rhythmic behaviors like rocking chairs or walking, in a manner typical of coupled oscillator systems (Richardson, Marsh, Isenhower, Goodman & Schmidt, 2007; Miles, Griffiths, Richardson, & Macrae, 2010; Schmidt & O'Brien, 1997). Even more intriguingly, these synchronous behaviors often result in increased scores on social measures like cooperation, trust, and connectedness (Hove & Risen, 2009; Miles, Nind, & Macrae, 2009; Wiltermuth & Heath, 2009; Valdesolo, Ouyang, & DeSteno, 2010). However, how these effects come about is unclear. How does engaging in interpersonal human synchrony, a behavior that is dynamically equivalent to synchronization with nonsocial stimuli (Repp & Keller, 2008) or any other coupled oscillator systems like fireflies (Buck & Buck, 1968) or even clocks on a wall (Bennett, Schatz, Rockwood & Wiesenfeld, 2002), result in changes in social variables?

For interpersonal synchrony to influence social variables, social mechanisms must be engaged. Studies have tested this idea by manipulating social context to influence interpersonal synchrony. For example, it has been demonstrated that both individual traits

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David W.-L. Wu, Department of Psychology, University of British Columbia, Vancouver, BC, Canada; Craig S. Chapman, Faculty of Physical Education and Recreation, University of Alberta, Edmonton, AB, Canada; Esther Walker, Department of Cognitive Science, University of California, San Diego; Walter F. Bischof, Department of Computing Science, University of Alberta; Alan Kingstone, Department of Psychology, University of British Columbia.

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Correspondence concerning this article should be addressed to David W.-L. Wu, Department of Psychology, University of British Columbia, Vancouver, BC, 2136 West Mall, V6T 1Z4. E-mail: david.wl.wu@gmail.com

and manipulating one's social orientation can affect both intentional and spontaneous interpersonal synchrony (Miles et al., 2010; Lumsden, Miles, Richardson, Smith, & Macrae, 2012; Schmidt, Christianson, Carello, & Baron, 1994). However, the social mechanisms driving the results are unknown.

Kirschner and Tomasello (2009) suggest two broad social mechanisms: one perceptual and one motivational. These mechanisms roughly parallel the distinction found in social neuroscience between the mirror system, for low-level perceptual processing of social stimuli, and the mentalizing system, for high-level social goal processing (Van Overwalle & Baetens, 2009). The former system necessarily requires perceivable stimuli, whereas the latter system does not. To avoid confusion over what we believe are overlapping theories in both fields, we term the low-level mirror/social–perceptual system as "social–perceptual" and the high-level mentalizing/social–motivation system as "social–motivational." To explore how these mechanisms may potentially impact interpersonal synchrony, we control one system (social–perceptual) while manipulating the other system (social–motivational).

To do so, we had participants conduct a synchronization–continuation tapping task (Semjen, Schulze, & Vorberg, 2000), either in the same room (SR) or in different rooms (DR) as naïve dyads (i.e., no confederates). Across many fields, this manipulation of physical proximity serves as a basic method for modulating behavior (Markus, 1978; Huguet, Galvaing, Monteil, & Dumas, 1999; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Richardson, Marsh, & Baron, 2007). The only investigation to our knowledge that has used this manipulation in a synchrony task context is Kirschner and Tomasello (2009). They found that young children could synchronize their drumming better to another person compared with a machine or just a drum sound. However, they did not discriminate between social–perceptual and social–motivational mechanisms (e.g., introducing a person not only changes the social context but also introduces a hand as a biologically relevant stimuli instead of an automated drum), and indeed offered both mechanisms as possible accounts for their findings.

We took great lengths to ensure that participants received the same physical stimulus across conditions to ensure any differences found would not be attributable to perceptual differences. The visual source of information between participants was controlled across all conditions by having participants' taps be represented by a flashing square on the monitor and by having participants seated (whether in the same room or not) in configurations where they could not see each other during the task. However, in addition to the visual flashes, SR participants also had auditory information from when their partners struck their keyboards. To test whether any differences between SR and DR could be accounted for by these keyboard noises we introduced a different-room auditory-coupled (DR + AC) condition, where participants could still hear each other tap through speakers. This allowed us to distinguish between the effects of shared space from the effect of auditory information alone on spontaneous interpersonal synchrony.

If interpersonal synchrony can be influenced alone by shared space, then SR dyads would show more tightly coupled tapping with one another compared with DR and DR + AC dyads.

Method

Participants

Sixty-eight participants from the University of British Columbia were either given course credit or paid $5 for their participation. They participated as dyads and were randomly assigned to the SR, DR, or DR + AC conditions.

Apparatus and Materials

Same room condition (SR). Two stations were setup in a room so that participants were sitting back to back, separated by approximately 5 feet. Each station consisted of a monitor, a keyboard, and a Sennheiser HD202 headphone. Matlab Psychtoolbox (Version 3) controlled stimulus presentation and recorded responses (Kleiner, Brainard, & Pelli, 2007). Participants sat approximately 57 cm away from their monitors (Figure 1A).

Different room condition (DR). Two stations were setup in neighboring rooms, both controlled by one computer in one of the testing rooms. The keyboard in the adjacent room was connected with an active USB extension (Belkin F3U130–16). The setup was otherwise identical to the SR condition (Figure 1B).

Different room auditory coupled condition (DR + AC). The setup was identical to the DR condition with the exception that two baby monitor systems (Vtech Crystal Sounds DECT Baby Monitor) were used so that participants could hear both the finger-to-key impact and the mechanical keyboard noise. A microphone was placed beside each keyboard and the corresponding speaker was placed in a filing cabinet at knee level of the other room. This allowed participants to clearly hear each other tapping, while preventing the squeal of feedback if the speakers were placed too close to the microphones. The average sound level intensity difference from tapping between in SR and DR + AC set-ups was 1 dB (Realistic Sound Level Meter 33–2050, accuracy = ± 2 dB at 114 dB). We also tested the sound delay of the baby monitors with an oscilloscope and found it to be negligible (12 ms, which is less than the frame rate of 60 Hz).

Stimuli

We created a program where pressing an assigned key would cause a white square, either on the top half of the screens or on the bottom half of the screens, to flash for 333 ms. Squares were 2.7 cm × 2.7 cm and were centered 3.95 cm above or below the screen center. Participant A hit 'V' to control the top square; Participant B hit 'N′ to control the bottom square.

Procedure

Participants were informed that they would be doing a tapping task in pairs, and their main task was to keep time with their own auditory beat (either drum or guitar, synthesized in Logic Pro 8) in the synchronization phase, and to continue this beat in the continuation phase. Participants were each assigned different sounds to promote the noncollaborative nature of the task. Based on pilot work the beats were played at 60 beats per minute (bpm). This relatively slow interonset interval (IOI) was chosen because we used visual stimuli

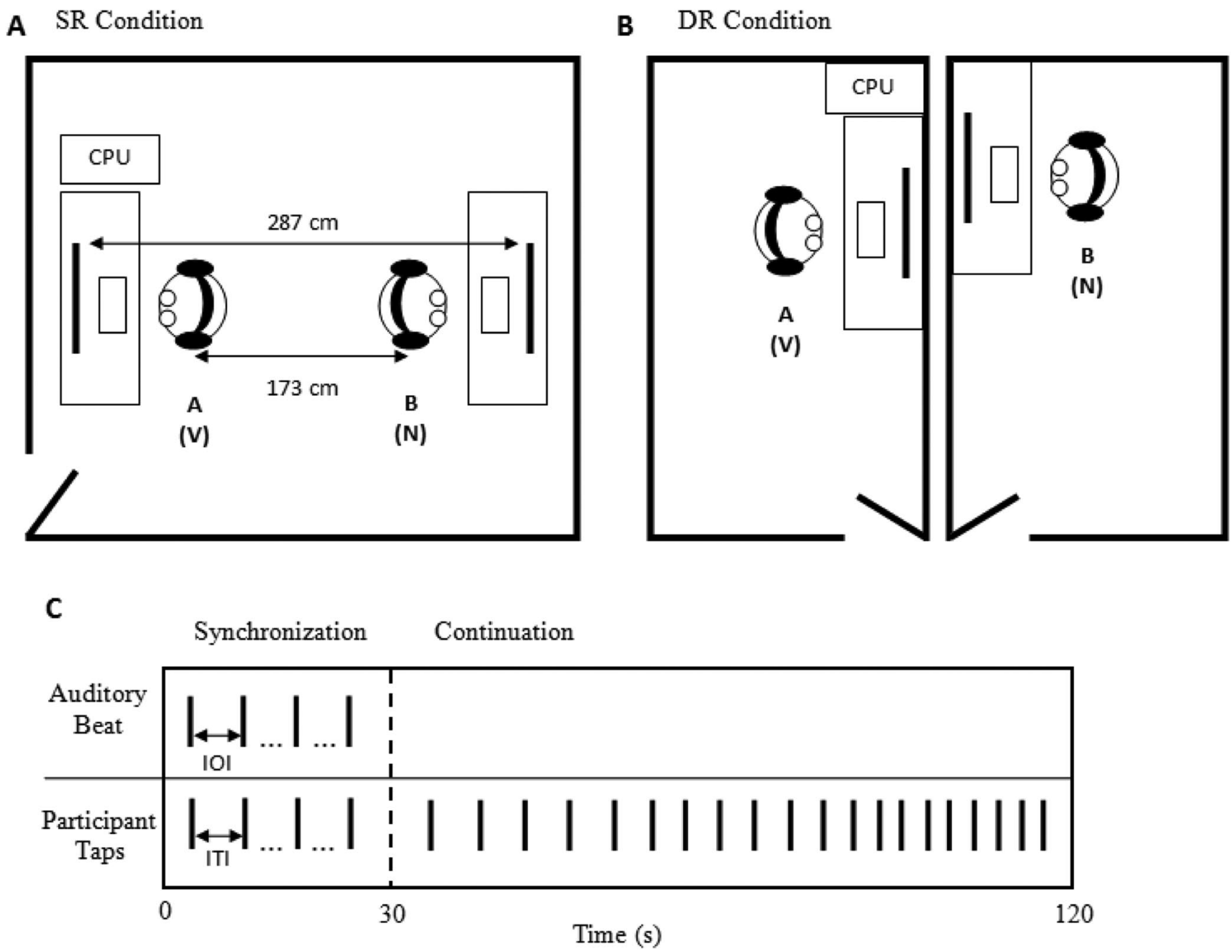

Figure 1. A, Room setup for the same room (SR) condition. Arrows depict distance between monitors and distance between participants. Letters in parentheses correspond to the key that Participant A or Participant B had to tap. B, Room setup for different room (DR) condition. DR and DR + AC participants had full knowledge that their partner was on the other side of the wall. C, Depiction of a typical synchronization-continuation trial. Small vertical bars represent the onsets of beats and taps. Interonset interval (IOI) is the time between computer generated beat onsets, whereas intertap interval (ITI) is the time between participant generated tap onset. Participants synchronize with the beat in the synchronization phase, and attempt to maintain the beat in the continuation phase. Although only 4 beats are shown in the synchronization phase, the actual synchronization phase involved 30 beats (IOI = 60 bpm). In this example, the participant speeds up during the continuation phase, a common occurrence during our experiment.

(i.e., flashing squares) to represent participant taps, and the fidelity of the visual system is relatively slow (Repp & Penel, 2002).

Trials began with a 30-s synchronization phase. During this phase participants could hear their respective auditory beat and promptly attempted to tap (with the index finger of their dominant hand) in synchrony with it. After the synchronization phase, the trial immediately entered a 90-s continuation phase. During this phase, the auditory beat was no longer presented and participants were instructed to maintain the rhythm they had been matching during the synchronization phase (see Figure 1C). Importantly, participants were not told to synchronize with each other. To provide visual feedback of performance, every time participants tapped their assigned key, their square flashed on both monitors. Participants were given a secondary task to evaluate both their own and their partner's performance at staying with the beat. This secondary task reinforced the idea that their main task was to stay on beat independent of how their partner was doing, and also ensured that participants would pay attention to the squares on the screen (e.g., they would not merely close their eyes while tapping their key).

Participants in the DR and DR + AC conditions had full knowledge about the dyadic nature of the task. As with the SR condition, both participants sat in the same waiting area and were briefed about the experiment together. In the DR + AC condition participants were also told they would be able to hear each other via the baby monitors.

The tapping task consisted of four trials. Trials 1 and 2 served as practice trials. In Trial 1, only Participant A performed the task, and in Trial 2, only Participant B performed. In the critical 3rd and 4th trials, participants engaged in the tapping task simultaneously. In the synchronization phase, both participants could hear both the drum and guitar beats, which were played simultaneously.

Data Analysis

Data from two dyads were discarded because of a participant not completing the task correctly, leaving a total of 11 pairs for the SR and DR conditions and 10 pairs for the DR + AC condition.

Adaptation index. Adaptation indices measure how participants tapped relative to each other on a tap-by-tap basis. However, because of an increased amount of noise generated from our long IOI, common measures of synchrony, such as cross-correlations or spectral analysis (Konvalinka, Vuust, Roepstroff, & Frith, 2010; Lumsden et al., 2012), were inadequate. Thus, we used a measure of adaptation based on recent tapping models for single tappers (e.g., Jacoby & Repp, 2012). These models predict the time of the next tap from the phase difference between the beat and the previous tap. We extended this approach by computing a phase-based adaptation index for dyads of tappers. The idea for this phase-based adaptation is simple: if there is a tendency to synchronize, the longer Participant A's tap occurs after Participant B's tap (i.e., a larger positive B-A asynchrony), the more likely it is for Participant A to tap faster (i.e., reduce the intertap interval [ITI] to reduce the asynchrony), and vice versa. Thus, we plot the change in ITI of a participant as a function of the asynchrony between the immediately preceding participant taps. We then compute the slope of a linear regression through all plotted points (excluding outliers outside a window of 0.5 s, or half the original IOI, in each direction). In this case, a negative index value (or slope of the regression line) indicates that as asynchronies between participant taps gets larger, the subsequent rate of the following taps will get quicker (a negative ITI change), whereas a positive index value indicates that as asynchronies get larger, the subsequent rate of tapping will slow (a positive ITI change). For example, Participant A and B start completely synchronized (no asynchrony). When A starts tapping quicker (asynchrony increases), B may also start tapping quicker (negative ITI change) to synchronize, creating a negative index value. However, if B doesn't change their pace, there index value would be zero. If B taps slower (positive ITI change) to create a further discrepancy, the index value would be positive.

Adaptation index values were computed for each participant and averaged across Trials 3 and 4. To ensure that any differences were not an artifact of our experimental setup, we also compared the adaptation values with the average adaptation values obtained for arbitrary, unrelated pairs of participants in the same experimental condition (i.e., a randomized control).

Results

Analysis of Adaptation

Average adaptation values for each condition are displayed in Figure 2. A one-way ANOVA revealed a significant between-subjects effect of room condition $F(2, 61) = 11.98$, $p < .001$, $\eta_p^2 = .28$. Post hoc Tukey's HSD tests revealed that the adaptation index was less in SR than in DR, $p < .001$, and less in SR than in DR + AC, $p = .008$. The difference between DR and DR + AC was not significant, $p > .05$. Paired *t* tests found all adaptation values to be less than randomized control values, all *p*s $< .004$. These data indicate that SR dyads adapted more to each other than DR and DR + AC dyads, though all dyads adapted to each other significantly more than chance.

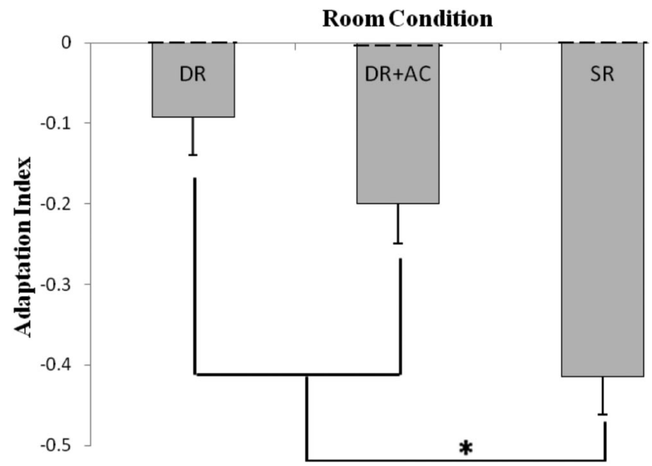

Figure 2. Average adaptation indices of participants across conditions (DR: $n = 22$; DR + AC: $n = 20$; SR: $n = 22$). The star shows that individuals in SR dyads were significantly stronger adapters compared with individuals in DR ($p < .001$) and DR + AC ($p = .008$) dyads. The dashed lines represent the randomized control values for each condition. Error bars represent SEM.

Discussion

Our study shows that the manipulation of an extrinsic social variable—sharing space with another participant—influences one's tendency to automatically engage in coordinated tapping. We found that SR dyads were much more sensitive to each other's changes in tempo, resulting in the greatest degree of phase-based adaptation. Synchronization of the DR + AC dyads fell between DR and SR dyads, indicating that while auditory cues improve synchrony (Demos, Chaffin, Begosh, Daniels, & Marsh, 2012) they cannot fully account for the difference between DR and SR dyads. As asynchronies between participants increased, participants compensated by speeding up their subsequent tap. This result converges with current tapping models (Jacoby & Repp, 2012; Vorberg & Schulze, 2002) and recent empirical evidence (Konvalinka et al., 2010). Our results contribute to current theoretical understandings of interpersonal synchrony and social proximity in several ways.

First, our results support the idea that there is a fundamental and automatic social drive to synchronize between persons as a way to form interpersonal connections with one another (Baumeister & Leary, 1995; Marsh et al., 2009; Kirschner & Tomasello, 2009). Given that the physical properties of the stimulus were controlled, and the task was orthogonal to mutual following, we believe that forming interpersonal connections may be powerful enough to override existing task goals such that there is greater mutual following even when participants drift off tempo. To do so, the saliency of a partner's stimulus may be increased, and this would drive participants toward tighter coupling. However, the motivation to form a connection may be much greater when the social conditions are optimal, that is, when in the physical presence of another individual there is a greater potential for social interaction (e.g., Laidlaw et al., 2011), so it would be advantageous to rapidly form connections. Although the existence of stronger perceptual cues may increase this motivation (there is some difference between DR and DR + AC dyads), it is social context that is a much stronger determinant.

We can also infer from our findings the relative importance between the two proposed mechanisms that drive interpersonal synchrony. The fact that we found some degree of adaptation in all conditions suggests that the social–perceptual (i.e., mirror system) might not be necessary in interpersonal synchrony. It seems unlikely that a flashing square would have enough biological relevance to engage the mirror system (given the evidence that even biological relevant action viewed on TV fails to elicit a mirror system response, Shimada & Hiraki, 2006). Indeed, studies have shown that cues associated with agency, but a nonspecific action (like the visual cues used in the current study), activate core areas in the mentalizing system, and not the mirror system (Ramnani & Miall, 2004). These mentalizing areas include the medial prefrontal cortex (especially the paracingulate cortex) and the associated temporoparietal junction[1] but not the premotor cortex or anterior intraparietal sulcus, both of which are thought to be key components of the mirror system (Ramnani & Miall, 2004; Van Overwalle & Baetens, 2009; Walter et al., 2004). Although at first blush this conclusion appears to conflict with EEG evidence of the mirror system being engaged during interpersonal synchrony (Tognoli, Lagarde, DeGuzman, & Kelso, 2007), it is worth noting that Tognoli et al. (2007) questioned whether their mirror system neuromarker was "unique and specific to social behavior or [whether it] is a multifunctional mechanism shared with other forms of perceptuo-motor coupling, even with nonhuman agents." Our results would suggest that the neuromarker found by Tognoli et al. (2007) was a multifunctional mechanism.

By finding that social context can influence tapping behavior independently of any differences in perceptual input, we suggest that the social–motivational system may be a key mechanism modulating interpersonal synchrony. This brings into question whether the amygdala, important for theory-of-mind (Gupta, Duff & Tranel, 2011), the development of trust (Koscik & Tranel, 2011), and social proximity (Kennedy, Gläscher, Tyszka, & Adolphs, 2009), may be an important neural correlate for interpersonal synchrony. It may be the amygdala that subserves the "social glue" that results from social coordination.

More generally, our study sheds light on current theoretical understandings of psychological distance. There is abundant literature on the study of the interrelatedness of psychological distances, such as spatial distance, temporal distance, and social distance (see for a review, Trope & Liberman, 2010). For example, experiments by Stephan, Liberman, and Trope (2010) show how social distance, as measured by politeness in language, can affect, and be affected by, the perceived spatial and temporal distances of the target of their communication. Our study goes further by not only supporting the idea that participants may dynamically behave in a manner that manipulates one dimension of distance (decreased temporal distance by increasing synchronous tapping) as a means to influence another dimension of distance (decreased social distance by increasing connectedness; Hove, 2008), but this relationship may be influenced by a third dimension of distance found in the environment (spatial distance). Thus, our study provides a relevant framework to understand the different aspects interpersonal synchrony—the dynamical action, the social effects, and the influence of the environment.

In conclusion, our study indicates that sharing a common physical space enhances incidental behavioral coordination. Importantly, we isolate the effects of the social environment from the perceptual environment (cf. Kirschner & Tomasello, 2009) and demonstrate that social proximity can influence relatively automatic perceptually driven behavioral processes like interpersonal synchronization, suggesting an important role for high-level social–motivational processes in interpersonal synchrony.

[1] Although Ramnani and Miall (2004) found differential activation in what they suggested was the posterior superior temporal sulcus—a mirror system area, the anatomical definitions provided by Van Overwalle and Baetens (2009) suggest it would more accurately be labeled as the temporoparietal junction—a mentalizing system area. Furthermore, differential activation of core mirror system areas (e.g., ventral premotor cortex) was only found when specificity of the cue was factored in. One possibility suggested by Ramnani and Miall (2004) was that cue specificity coupled with agency allowed for the mirror system to engage mental imagery of other's actions. However, our task was not designed for mental imagery (i.e., participants performed concurrently), and our cues did not have the specificity, predictability, or direct observation learning that Ramnani and Miall's task had. We believe our task design is sufficiently divergent to conclude that it is unlikely the mirror system would be engaged.

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