Mixing Behavior: Interaction between Materials and Tool Size

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Introduction

Mixing is one of the human behaviors used to transform the properties of substances that exist in the environment. Through the mixing, substances with different chemical compositions are blended. Mixing has a couple of intentions. It may melt a solid into a liquid, by which the behavior generates a state with new chemical compositions and transforms its surface arrangement. The mixing process will provide affordances of being ingestible for us. Mixing behaviors must necessitate appropriate methods of using tools. This study will reveal the interaction of the behavior with tool types that people use to fulfill the mixing.

Purpose

This study investigated to ascertain effects of different ingredients and tool types on the hand movement for uniform mixing.

Method

Participants. 4 undergraduate students (3 males and 1 female).

Experimental Design. 4 conditions = 2 ingredients (OW / SS) x 2 tools (Short / Long).

OW condition : Oil (50 ml) & Water (50 ml)
SS condition : White Sugar (60 g) & Brown Sugar (60 g)
Short condition : Short (18cm) chopsticks (Figure 1)
Long condition : Long (33cm) Chopsticks (Figure 1)

Trials. Each participant made two trials in an individual condition.
i.e. 2 ingredients (OW / SS) x 2 tool lengths (Short / Long) x 2 trials = 8 trials

Apparatus. The height of the table-top was adjusted to 10 cm below the participant's elbow height (Figure 2) . The bowls (stainless bowl , diameter: 20 cm, height: 8 cm) were placed on the table. The sensor of PATRIOT was attached on the back of a participant's right hand to record their hand movements.

OW condition : A bowl contained Oil & Water, not yet mixed.
SS condition : A bowl contained White Sugar & Brown Sugar, not yet mixed.

Procedure . Participants were asked;

1)to stand in front of a table.
2)to hold chopsticks (short or long) with their right hands.
3)to stir ingredients with chopsticks.
4)to continue the action at least 60 seconds
5)to declare when they recognized
the ingredients were uniformly stirred.

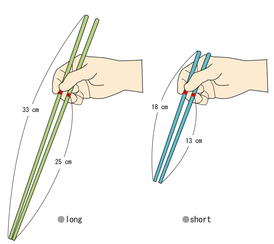


Figure 1. Length of Chopsticks

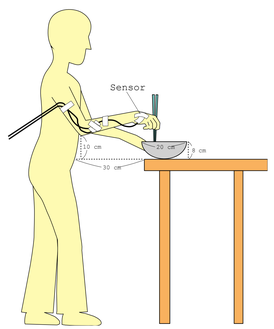


Figure 2. Experimental Apparatus

Results

Palmar/dorsal flexion (circular motion angle) of a participant's wrist were analyzed by STFT, RQA, and DFA. The results can be summarized as follows:

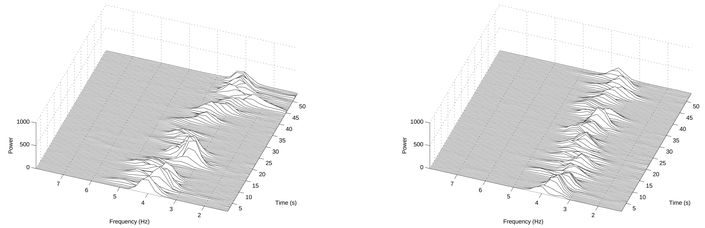
1)Mixing liquids by using short chopsticks provide the most regular motion, stirring with high velocity.

2)Mixing sugars by using long chopsticks provide rather non-structured and irregular motion, stirring by both high and low circular movements in the beginning and then shifting to lower circular movement. In other words, stirring quickly varied from the fast to the slow velocity in the first stage then, slowed to the end.

3)Tools and ingredients are interactive in uniform mixing.

4)The goal-directed motion of mixing can be flexible to accommodate ingredients and tool properties. This flexibility is considered to be one essential element of animal's intelligence argued by E. J. Gibson.

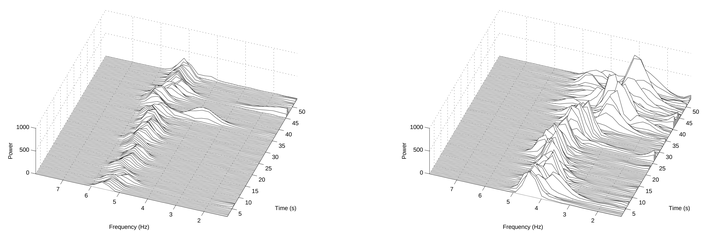
Spectrum Analysis, STFT (short-term Fourier transform) :



(a) Short Chopsticks (b) Long Chopsticks

Figure 3. Representatives of STFT under the OW condition

The short-term power spectrums of short and long chopsticks in the OW condition. (a) When the short chopsticks were used, power was distributed in wide range of frequencies in the beginning stage of stirring, but the peak power shifted to relatively lower frequencies at the last stage. (b) The width of the power distribution on using the long chopsticks was narrower than that of the short chopsticks. Furthermore, the range of frequencies on which power concentrated remained stable throughout the stirring process.



(a) Oil and Water (b) White and Brown Sugars

Figure 4. Representatives of STFT under the Short Chopsticks condition.

The short-term power spectrums under two ingredient conditions by using the short chopsticks were illustrated. (a) In OW condition, the peaks of power were limited to the narrow bandwidth of frequencies that was consistent and did not change throughout the stirring process. (b) In contrast in SS condition, the range of frequencies that had strong power was narrow at the beginning of stirring; however, the range became gradually wider toward the end of the process.

RQA (Recurrence Quantification Analysis) :

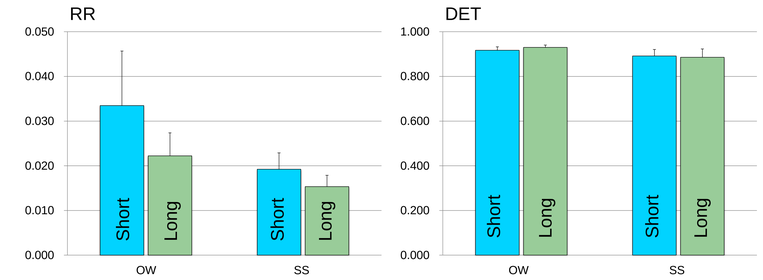


Figure 5. Mean Measures under four conditions (OW / SS x Short / Long)

The mean recurrence rate was higher in the short condition than in the long condition ($p < .10$), and the recurrence rate was higher in the OW condition than in the SS condition ($p < .05$). As for determinism, the value of the short condition was higher than that of the long condition ($p < .05$).

DFA (Detrended Fluctuation Analysis) :

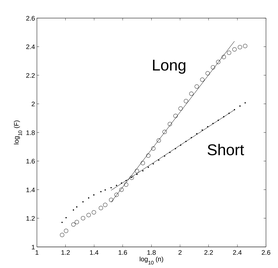


Figure 6. Representatives of results of DFA

Double-logarithmic plot of fluctuation *F* vs. interval length *n*.

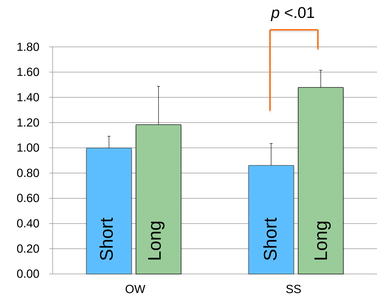


Figure 7. Mean αs under four conditions

Mean α of the long condition was significantly higher than that of short condition under the the SS condition ($p < .01$).