Hand-Mixing with Chopsticks: Regulations of Hand Movements by Ingredient Properties and Tool Length

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Little research has been carried out on mixing skills used in everyday life, such as making sauces and cocktails, and melting sugar into coffee, though scientific studies on *mixing* have been conducted, chiefly in the chemical engineering field. The findings suggest that mixing should be regarded as the combination of hand movements and use of a tool. From this point of view, it is necessary to describe interaction between hand and tool movements using kinesiological and psychological approaches so as to reveal a process that allows for uniform mixture.

Experiment 1

Relationship between hand movements and ingredient properties

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 participated in two trials in an individual condition,
that is, 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 participants' elbow height (Figure 2). The bowls (diameter: 20 cm, height: 8 cm) were placed on the table. The transmitter of PATRIOT was attached to the back of the participants' right hand to record their hand movements.

Procedure. Participants were asked to

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

Figure 1. Length of Chopsticks
Long chopsticks are used in the preparation of Japanese food, and are not designed as a tool for eating

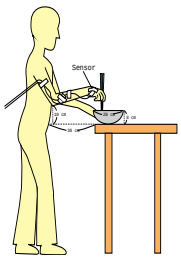


Figure 2. Experimental Apparatus

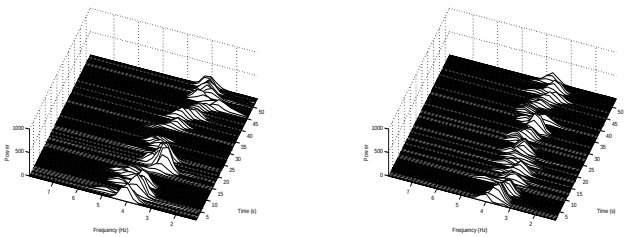
Results

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

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

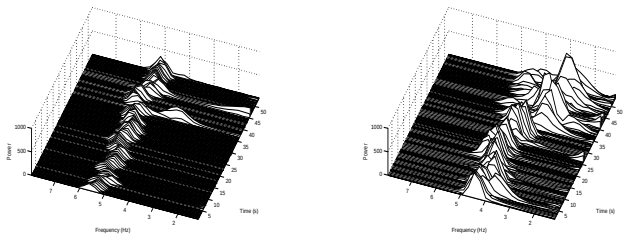
2) Mixing the sugars using long chopsticks provides a rather non-structured and irregular motion, stirring with varying velocity, with both high and low circular movements in the beginning and then shifting to lower circular movement.

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 short chopsticks were used, power was distributed in a wide range of frequencies in the initial stages of stirring, but the peak of power shifted to relatively lower frequencies at the final stage. (b) The width of the power distribution while using long chopsticks was narrower than while using short chopsticks. Furthermore, the range of frequencies on which power was 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 using short chopsticks were illustrated. (a) In the OW condition, the peaks of power were limited to the narrow bandwidth of frequencies, which was consistent throughout the stirring process. (b) In contrast, in the SS condition, the range of very powerful frequencies was narrow at the initial stages of stirring; however, the range became gradually wider toward the end of the process.

RQA (Recurrence Quantification Analysis):

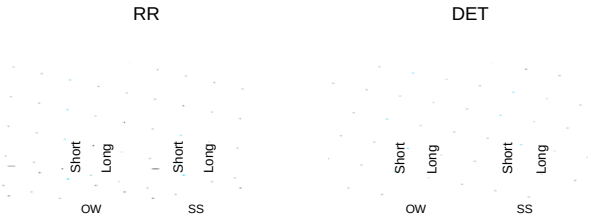


Figure 5. Mean Measures under four conditions (OW/SS x Short/Long)
The mean recurrence rate was higher in the short condition than in the long condition ($p < .10$), and the recurrence rate was higher in the OW condition than in the SS condition ($p < .05$). As for determinism, the value of the short condition was higher than that of the long condition ($p < .05$).

Experiment 2

The effect of visual perception on tool control and solubility of ingredient

Method

Participants. Three female adults.

Experimental Design. 4 conditions: 2 amounts (100 g/200 g) of ingredients (sugar) x 2 visual conditions (eyes open/eyes closed).

Apparatus. The height of the table-top was adjusted to 10 cm below the participants' elbow height (Figure 2). The bowls (diameter: 20.5 cm, height: 8 cm) were placed on the table. The transmitter of PATRIOT was attached to the upper end of a stick to record their stirring movements.

Procedure. Participants were asked to

1)stand in front of a table.
2)hold a stick (24 cm) with their right hands.
3)move the stick in the lateral direction for mixing sugar with water (200 ml).
4)continue the action for 120 s with eyes open, or with eyes closed.

Figure 6. Experimental Apparatus.
A movable (back and forth) guide, which restricts the movement of the stick in the lateral direction, was attached above the bowl.

Measurement and Calculation. Brix (solubility of sugar) were measured three times while stirring. *Works* of hand motion while stirring were computed.

Results

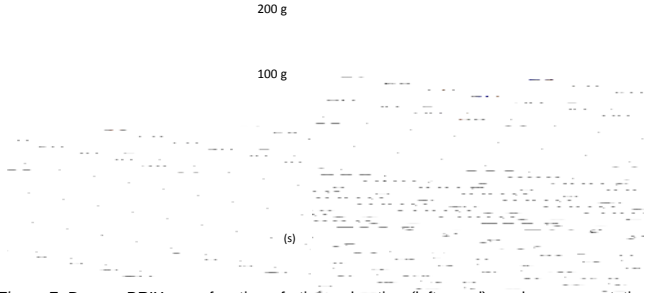


Figure 7. Degree BRIX as a function of stirring duration (left panel), and a representative of degree BRIX for *work* of stirring in two conditions (right panel).
The ratio of brix to *works* was higher in the visually guided condition than in the non-visually guided condition.

Concluding Remarks

- Tools and ingredients are interactive in uniform mixing.
- The goal-directed motion of mixing can be flexible to accommodate ingredients and tool properties.
- Visually guided stirring is more effective than non-visually guided stirring.