

# EFFECTS OF THE REFERENCE STIMULUS RANGE ON THE PERFORMANCE IN THE FOUR DIFFERENT VERSIONS OF THE DUO-TRIO TEST



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# DUO-TRIO DISCRIMINATION TEST

- It is commonly used overall discrimination test in which the specific sensory attribute is not described.
- The instruction asks the judges to choose the same stimulus as the reference.
- Yet, in Food business, the test procedure has often been used with slight variations, not fully acknowledging the effect of such variations on the perception and decision process of the test.
- In the Thurstonian modeling context, the generally assumed decision strategy is the **'comparison of distances' (COD) cognitive strategy**.
- Yet, in theory depending on the test and experimental design, decision strategies other than COD are also possible to be used.



# DUO-TRIO DISCRIMINATION TEST (CONT'D)

- According to **the range of reference**, it is applied in two different conditions (Meilgaard, M., Civille, G. V., & Carr, B. T. 1991).

## Balanced reference mode



- All stimuli are provided as the reference.
- It is generally studied method in science field.
- Probabilistic modeling such as Thurstonian modeling for the duo-trio using comparison of distances (COD) strategy is based on this balanced format.

## Constant reference mode



- The reference is fixed.
- It is generally used method in case of the presence of original (or reference) product in food industry.
- Theoretically, not only COD but also alternative strategies such as  $\beta$ - and  $\tau$ -strategy are possible.

# DUO-TRIO DISCRIMINATION TEST (CONT'D)

- According to **the position and number of reference**, variants of modified duo-trio discrimination have been suggested for its efficiency (Rousseau, B., Stroh, S., & O'Mahony, M. 2002, Lee, H.-S., & Kim, K.-O. 2008)

The traditional **Duo-Trio** with the reference tasted **First (DTF)**



The **Duo-Trio** with the reference tasted in the **Middle, between the two test samples (DTM)**



The **Duo-Trio** with the reference tasted twice, **First and last as a Reminder (DTFR)**



# DUO-TRIO DISCRIMINATION TEST (CONT'D)

- In literature, the performance of variously modified duo-trio tests has been studied **based on COD strategy**, only under the balanced reference condition.

	Comparison of performance	Experimental design	Stimuli
Rousseau, Stroh and O'Mahony(2002)	① DTF < <b>DTM</b> (comparison of only common sequence, that is 'AAB', 'BBA')	Fixed design	Orange flavored beverages with sugar
Lee and Kim(2008)	① DTM ≤ DTF ≤ <b>DTFR</b>	Roving design	NaCl/water model system
Kim, Lee and Lee(2010)	① DTF ≅ DTM < <b>DTFR</b> ② <b>DTF</b> > DTM (common sequence)	Roving design	Tomato juice with added salt

# POSSIBLE EXPLANATION FOR THE SUPERIORITY OF DTFR

1. The reminder provided at the end of the test enabled the direct comparison between the reference and the comparison sample, making the COD strategy more efficient.
2. Procedural modifications in DTFR may have induced a change in its decision strategy.

## AB-X matching



AB-X matching = duo-trio with balanced reference mode:  
 $\beta$ - as well as  $\tau$ - strategy can be used

## DTFR



AB-X matching using  $\beta$ -strategy

# 4I-RX

- It is **procedurally equivalent to the dual-pair(4I-AX)** method except that the first stimulus in each pair is fixed to a reference product.

## The first stimulus-fixed dual-pair (4I-RX)

- Like DTFR, direct comparison between the reference and the comparison sample is possible.

### 4I-AX (Dual-pair)



Variable A



Variable A

### 4I-RX



Reference

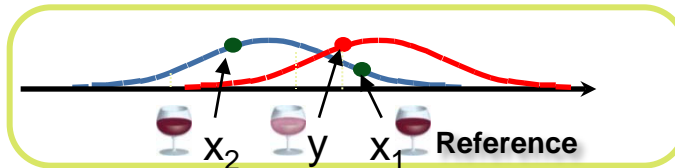


Reference

# PROBABILISTIC MODELING FOR 4IRX

## Duo-Trio

### Perceptual presentation & Decision rule



- $P(c) = P(|x_2 - x_1| < |y - x_1|)$

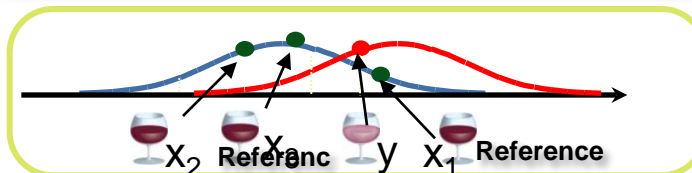
### Psychometric function

$$P_c = 1 - \Phi\left(\frac{\delta}{\sqrt{2}}\right) - \Phi\left(\frac{\delta}{\sqrt{6}}\right) + 2\Phi\left(\frac{\delta}{\sqrt{2}}\right)\Phi\left(\frac{\delta}{\sqrt{6}}\right)$$

## 4IRX

### (Modified Dual-pair)

### Perceptual presentation & Decision rule



- $P(c) = P(|x_2 - x_1| < |y - x_3|)$

### Psychometric function

#### Duo-trio COD strategy

$$P_c = 1 - \Phi\left(\frac{\delta}{\sqrt{2}}\right) - \Phi\left(\frac{\delta}{\sqrt{6}}\right) + 2\Phi\left(\frac{\delta}{\sqrt{2}}\right)\Phi\left(\frac{\delta}{\sqrt{6}}\right)$$

#### Dual-pair strategy

$$P_c = [\Phi(\delta / 2)]^2 + [1 - \Phi(\delta / 2)]^2$$



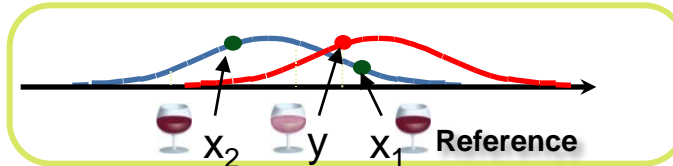
# OBJECTIVES OF THE PRESENT STUDY

- 1) To investigate the duo-trio performance under two different reference scheme for multiple pairs: **balanced reference mode (roving multiple references)** and **constant reference mode (a fixed single reference)**
- 2) To investigate the performance of variants of modified duo-trio test, under not only balanced reference mode, but also constant reference mode: **DTF, DTM, DTFR** and **4IRX**

# PROBABILISTIC MODELING: FIXED DESIGN (ONLY A PAIR OF STIMULI)

Duo-Trio with constant reference

Perceptual presentation & Decision rule



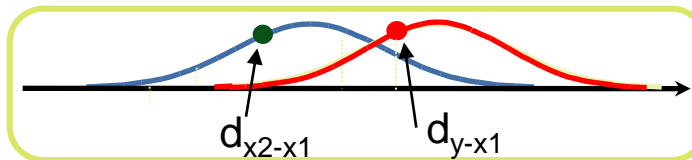
- $P(c) = P(|x_2 - x_1| < |y - x_1|)$

Psychometric function

$$P_c = 1 - \Phi\left(\frac{\delta}{\sqrt{2}}\right) - \Phi\left(\frac{\delta}{\sqrt{6}}\right) + 2\Phi\left(\frac{\delta}{\sqrt{2}}\right)\Phi\left(\frac{\delta}{\sqrt{6}}\right)$$

2-AFCR

Perceptual presentation & Decision rule



- $P(c) = P(y - x_1 > x_2 - x_1)$

Psychometric function

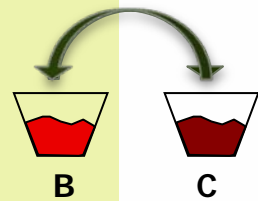
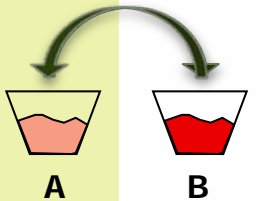
$$P_c = \Phi(\delta / \sqrt{2})$$

# MATERIALS AND METHODS

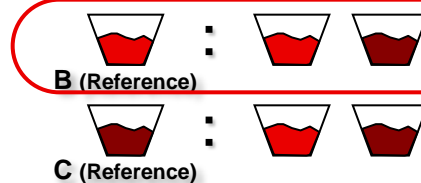
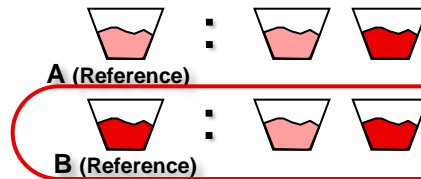
- **Samples**

- tomato juice which adds the salt

## Stimuli pair



## Balanced reference mode



## Constant reference mode



- **Subjects**

- 24 students in Ewha Womans University

# INVESTIGATED VARIANTS OF MODIFIED DUO-TRIO DISCRIMINATION TEST

## In Balanced & Constant reference mode

The traditional **Duo-Trio** with the reference tasted **First (DTF)**



The **Duo-Trio** with the reference tasted in the **Middle**, between the two test samples (**DTM**)



The **Duo-Trio** with the reference tasted twice, **First** and last as a **Reminder (DTFR)**

iv



The first stimulus-fixed dual-pair (**4IRX**)

# MATERIALS AND METHODS<sub>(CONT'D)</sub>

## Experimental Design

Group 1  
(N=12)

Constant ref. -> Balanced ref.

Session 1

Practice session

Session 2

Warm-up  
Duo-trio with  
**constant**  
reference

Session 3

Warm-up  
Duo-trio with  
**constant**  
reference

AFTER  
1WEEK  
K

Session 4

Duo-trio with  
**balanced**  
reference

Session 5

Duo-trio with  
**balanced**  
reference

Group 2  
(N=12)

Balanced ref. -> Constant ref.

Session 1

Practice session

Session 2

Duo-trio with  
**balanced**  
reference

Session 3

Duo-trio with  
**balanced**  
reference

AFTER  
1WEEK  
K

Session 4

Warm-up  
Duo-trio with  
**constant**  
reference

Session 5

Warm-up  
Duo-trio with  
**constant**  
reference

Maximum 5  
times of tasting  
stimuli pair,  
including the  
reference

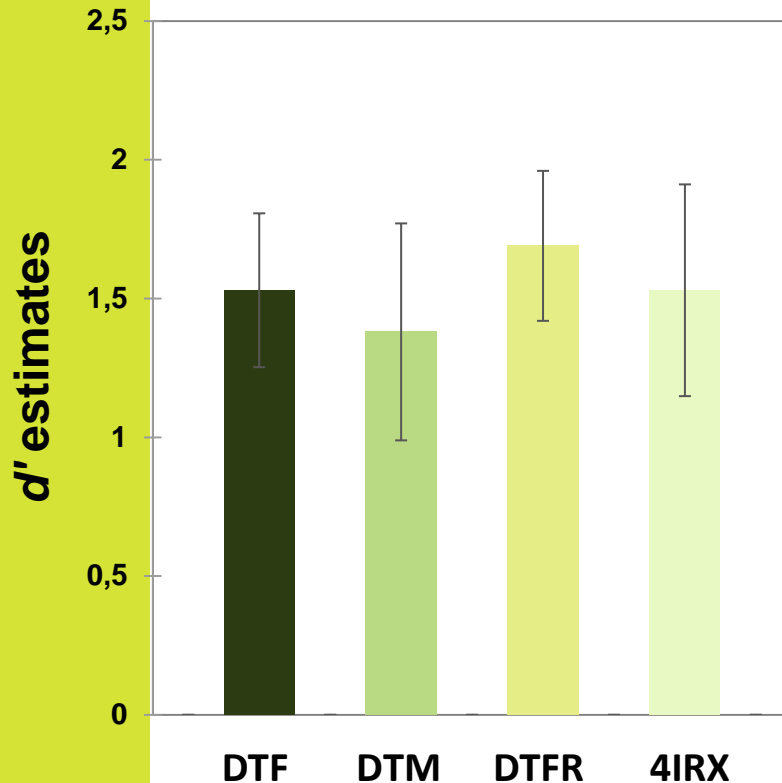
# MATERIALS AND METHODS<sub>(CONT'D)</sub>

## ● Data analysis

- For three versions of duo-trio test and first stimuli-fixed dual-pair(4IRX), estimates of  $d'$  were obtained based on 'comparison of distances(COD) strategy' from R-package sensR(Christensen & Brockhoff, 2008) and IFPrograms (Institute for Perception, Richmond, VA).
- For AB-X matching, estimates of  $d'$  were obtained from the proportion of correct responses using tables (Macmillan, N. A. & Creelman, C. D. 2005)
- $d'$  values were corrected regarding over-dispersion (Beta-Binomial, IFPrograms).

# RESULTS

## 1) Balanced reference mode (roving multiple reference)



- In balanced mode,  $d'$  of DTFR tended to be little higher as previous studies.
- 4IRX resulted in equivalent  $d'$  with DTF.
- Although the number of stimuli in DTFR and 4IRX is more than that in DTF and DTM, they showed comparable  $d'$ .

- No. of responses for each  $d' = 384$  (24judges X 8set/session X 2session)

# RESULTS<sub>(CONT'D)</sub>

## 1) Balanced reference mode (roving multiple reference)<sub>(cont'd)</sub>

Protocol	$P_c$	$d'$ based on COD	$d'$ based on ABX( $\beta$ )	ratio to DTF
DTF	67%	1.53		1
DTM	64%	1.38		0.90
DTFR	70%	1.69	1.53	1
4IRX	67%	1.53		1



# RESULTS<sub>(CONT'D)</sub>

## 1) Balanced reference mode (roving multiple reference)<sub>(cont'd)</sub>

### CHECKING THE HYPOTHESIS FOR ALL PREVIOUS STUDIES

#### Theoretic-detection model

DTF: duo-trio COD strategy

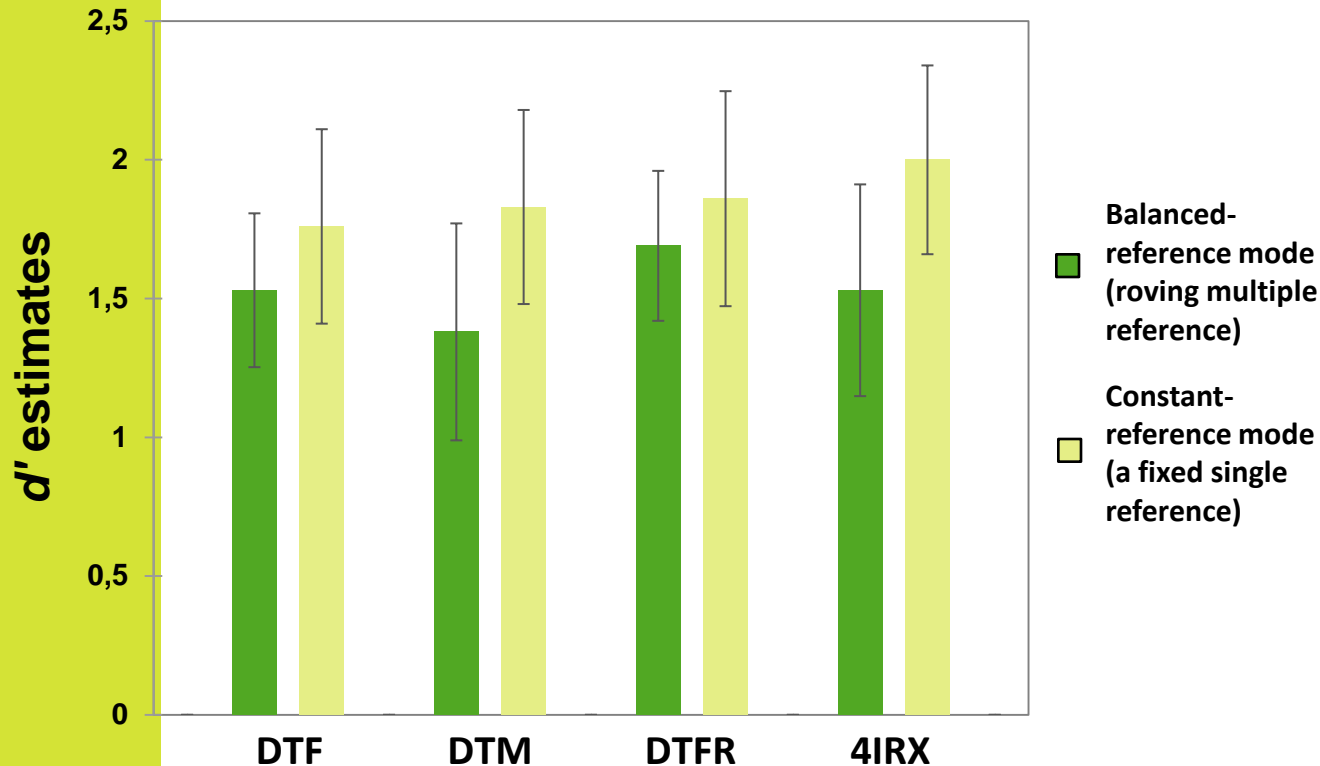
DTFR: AB-X  $\beta$ -strategy

4I-RX: duo-trio COD strategy

	DTF	Ratio of DTFR to DTF	Ratio of 4IRX to DTF
Lee and Kim(2008)	1	1.03	-
Kim, Lee and Lee(2010)	1	1.08	-
Present study	1	1	1
Average	unity	1.04 $\pm$ 0.04	1

# RESULTS<sub>(CONT'D)</sub>

## 2) Constant reference mode (a fixed single reference)



- The performances of constant reference mode, tends to be higher than those of balanced reference mode (2-tailed t-test,  $p \leq 0.05$ ).

- No. of responses for each  $d' = 384$  (24judges X 8set/session X 2session)

# RESULTS<sub>(CONT'D)</sub>

## 2) Constant reference mode (a fixed single reference)<sub>(cont'd)</sub>

Protocol	$P_c$	$d'$ based on COD	$d'$ based on 2AFCR	$d'$ obtained in Balanced mode
DTF	71%	1.76	<del>0.78</del>	1.53
DTM	72%	1.83	<del>0.82</del>	1.38
DTFR	72%	1.86	<del>0.84</del>	1.69
4IRX	75%	2.00	<del>0.84</del>	1.53

# CONCLUSION

- **Constant reference scheme resulted in higher  $d'$  values than balanced reference scheme(2-tailed t-test,  $p \leq 0.05$ ). This could be due to the warm-up procedure, stabilizing the perceptual and decision dimension.**
- **Within identical reference mode, variants of duo-trio test showed slightly different  $d'$  values. They were not significantly different, but it is still possible that different cognitive decision strategy has been used.**
- **In balanced reference mode, DTFR and 4IRX seemed to use AB-X ( $\beta$ ) strategy and COD strategy same as DTF, respectively.**
- **In constant reference mode, 2AFCR strategy was not adopted in all protocols. Yet, with better familiarization with the reference, it is still possible that subjects might be able to use 2AFCR strategy in the duo-trio with constant reference scheme. More research is needed to determine the cognitive decision strategy used in the duo-trio with constant reference scheme.**

# CONCLUSION<sub>(CONT'D)</sub>

- In the present study,  $d'$  estimates were computed in the pooled data across subjects. Difference between subjects can exist and thus individual results should be investigated with enough repetition.
- Modification of protocol can elicit significant change in perception as well as decision process.
- Therefore, for accurate comparison either using  $P_c$  or  $d'$  estimates, the test procedure used in each experimental condition needs to be understood.
- In future research, it needs to be further investigated not only the effects of the range of the reference, but also the effects of the range of comparison products.



**Ewha Womans University**  
**Food Design/Ergonomics Lab.**

THANK YOU