International Journal of Health Sciences and Research
Vol.10; Issue: 9; September 2020
Website: www.ijhsr.org
ISSN: 2249-9571

Original Research Article

The Colour-Concept Stroop Effect- A Measure of Differences in Linguistic Conceptual Depth

Anne Varghese[1], Johhanna Jesuraja[2]

[1]Assistant Professor, Department of Speech Language Pathology, Dr MV Shetty College of Speech & Hearing, Maladi Court, Kavoor, Mangalore 575015. Karnataka, India.
[2]Speech Language Pathologist, Department of Speech Language Pathology, Ganga Hospital, Coimbatore 641043, Tamil Nadu, India.

Corresponding Author: Anne Varghese

ABSTRACT

Aim: The aim of the study was to develop colour-concept interference paradigm to explore the possibility of using the Stroop interference effect to measure differences in linguistic conceptual depth in children.
Method: The colour-concept Stroop test consisted of five tasks – Colour Naming (CN), Easy-Object Colour-Naming (EO-CN), Difficult-Object Colour-Naming (DO-CN), Easy-Object Naming (EO-N) and Difficult-Object Naming (DO-N). The participants were 30 preschool children, 15 male and 15 female, mean age 4.6 years and 4.7 years respectively, (range 4.3 to 4.11 and 4 to 4.9 years), selected randomly from two English medium urban schools.
Procedure: The picture stimuli were presented through power-point slides-show on a Dell laptop (screen width 14 inches by 7.8 inches). Each set started with a blank screen for 200 ms, followed by a fixation cross of 500 ms. The onscreen stimulus duration was 1.5 seconds. The children were instructed to name colours, the colour of easy and difficult objects and then name the easy and difficult objects. The verbal responses were recorded on Pratt software (version 6.0.33 updated, 2017) for reaction time analysis.
Results: The differences between the mean reaction time and mean interference between easy object colour naming and difficult object colour naming was significant.
Conclusion: The colour-concept Stroop interference paradigm can be used to measure differences in linguistic conceptual depth. The implications of these findings are found in the discussion.

Keywords: Stroop, Colour, Concept, Development, Semantics

INTRODUCTION

The Stroop Effect, named after John Ridley Stroop, is a phenomenon that occurs when one must say the colour of the ink a word is written in, rather than read the colour that the word spells. For example, the word 'blue' is written in red ink and the subject is required to say 'red' rather than read the word 'blue'. The Stroop effect is a demonstration of cognitive interference where the delay in the reaction time of a task occurs due to a cognitive mismatch in stimuli. [1] The anterior cingulate cortex and dorso-lateral pre-frontal cortical areas of the brain are some regions involved in the Stroop effect. [2] Several theories have been proposed to explain this effect, like, the automaticity hypothesis, selective attention, bottleneck theory, and parallel distributed processing theory. [3-5]

Some of the notable features of the Stroop effect are: i) that it yields highly reliable and stable measures of individual differences on the three tasks employed; ii) the individual differences in the three time scores from the Stroop test are reliable and maintain the same rank order of magnitude; iii) the Stroop test shows significant correlation with many complex psychological measurements; iv) despite significant improvement in colour naming with practice individual differences in colour naming speed show remarkably little interaction with practice; the subjects maintain the same rank order. [6]

For these reasons the Stroop has been used extensively to study as a measure of attentional capacity, cognitive control, and processing speed. The Stroop test along with other neuropsychological assessments is used to help in diagnosis and description of different psychiatric and neurological disorders. The Stroop paradigm provides a template for studying interference. Studies have shown that the Stroop effect can be used in other paradigms besides the colour-word paradigm. [6] *This paper attempts to create another paradigm called colour-concept interference paradigm,* which explores the possibility of using the Stroop interference to measure differences in conceptual depth in children.

Concepts are the foundation of knowledge and are also referred to as mental images, ideas, or processes which are necessary for the classification and organization of knowledge. The basis for a concept is a collection of simultaneous reconstructions of sensory and motor representations that have a high probability of being triggered by the same non-verbal or verbal stimulus. [7] A fully developed conceptual system is important for adequate receptive and expressive vocabulary skills; good communication, academic and social skills; and for personal or professional success.

Concepts are shared experiences built into memory over time and form the foundations for language and language development. The development of concepts begins in infancy and is rooted in sensory-motor inputs from the people and objects in the environment. The ability to discriminate characteristics common to a class of objects or ideas results in perceptual insights into the properties of objects and the relationships among them. These sensory-motor mental representations of objects are present even before children have the words for them. A well-established conceptual system assists language development at the time of first words acquisition, that is, if a child has adequate conceptual understanding of something, for example “cat”, then it learns the word for cat with facility by attaching the linguistic label ‘cat’ to the category of sensory motor experiences that it has already acquired about a cat.

Concept formation of objects in children is a dynamic process that evolves from simplistic semantic representations to mature semantic representations of objects over time. This is expounded in Piaget’s [8] observations that semantic development starts with adaptation, a process consisting of assimilation and accommodation. Assimilation is the cognitive process of integrating new perceptual or conceptual information into an existing schema, and accommodation the creation of new schema or upgradation of old schemata. The interplay of assimilation and accommodation precedes semantic development. This active process of building and maintaining concepts over time, aids in word acquisition, word retrieval and lexical semantic upgradation through time.

A fully matured conceptual system is a treasure house of information [9] that has been acquired over time through the consolidation of memories. The following example highlights this point. A comprehensive representation of an apple, for example, requires the integration of one’s episodic memories and general knowledge about an apple. The general knowledge about an apple comes from assimilating its perceptual attributes (red, round, smooth, crunchy, the smell etc); the uses (it is edible); the encyclopaedic knowledge about an apple (the academic information and literary references); and also one’s personal or episodic memories related to an apple. [9]

There is a relationship between degree of concept development and naming in children, that is, the accuracy of naming correlates with the degree of concept development of an item in the semantic system. This is because a fully developed concept has a range of related semantic representations associated with it. Children pass through these stages before a concept is fully encoded. Errors in naming occur because of gaps in knowledge, or due to fragile or shallow semantic representations. Therefore, it is possible that a child might use a word that he/she may not yet fully understand. [10] Consequently, it is also possible that a child can have adequate language skills according to test results yet faces problems fully comprehending what is heard or read.

It is, therefore, useful to have a simple tool that can assess the depth of concept development of objects in young children. Such an assessment is useful for speech therapists providing language intervention for children with language delays, for primary school teachers and parents concerned about the children's poor comprehension skills, and for researchers studying degradation of concepts in persons with dementia. *Therefore, this paper attempts to create a colour-concept interference paradigm* which explores the possibility of using the Stroop interference to measure differences in conceptual depth in children.

Colour-concept interference is based on the finding that children have a prepotent tendency to name the object than naming the colour of it. [11, 12] For example, Prevor and Diamond [12] studied the effects of colour–object interference in pre-schoolers and young school-age children. They investigated both object naming and colour naming of object picture, under four conditions, that is, congruent condition (familiar objects, drawn in their usual colour), an incongruent condition (familiar objects in anomalous colour), a neutral condition (familiar objects that have no particular colour associated with them), and a baseline colour-naming condition (un-nameable abstract shapes drawn in a colour). They found that (a) Children were faster and more accurate at naming the object presented than at naming its colour, (b) the reaction time for colour naming was longer for incongruent stimulus when compared to congruent or neutral stimulus and (c) children found it easy to name the colour of abstract shapes than naming the colour of nameable object. The results can be extended to infer that *naming an object has the potential to interfere with naming the colour of the objec*t. Earlier studies also show that the more meaningful a word the more interference it causes in studies involving semantic Stroop. [13, 14]

On this premise it can be hypothesized, *that differences in the conceptual knowledge of objects can produce differences in reaction times in colour-object naming tasks.* If so, then a significant difference in the reaction times, between colour-naming a familiar object versus an unfamiliar object, is evidence of differences in the conceptual knowledge or depth among them. This paper attempts to create a colour-concept interference paradigm to explore the possibility of using the Stroop interference to measure differences in conceptual depth in four to five year old children.

In order to explore this possibility the following null hypotheses were constructed.

i. The difference between the means of reaction time between Easy-Object Colour-Naming (EO-CN) and Difficult-Object Colour-Naming (DO-CN) is not significant.
ii. The difference between the means of interference between Easy-Object Colour-Naming (EO-CN) and Difficult-Object Colour-Naming (DO-CN) is not significant.

The objectives of the study were to:

i. obtain the mean reaction time for Easy-Object Colour-Naming (EO-CN)
ii. obtain the mean reaction time for Difficult-Object Colour-Naming (DO-CN)

iii. calculate the mean interference for EO-CN
iv. calculate the mean interference for DO-CN
v. see if the difference between the mean of reaction time for EO-CN and DO-CN is significant
vi. see if the difference between the mean of interference for EO-CN and DO-CN is significant

MATERIALS AND METHODS

The study was conducted in two phases- phase I and phases II. Phase I consisted of material development and phase II constituted the study.

PHASE I

Material development

The Colour-Object Stroop procedure followed by Cramer [11] was modified for the current study. Instead of congruent and incongruent form/object naming, four easy and difficult to name pictures of objects were used. Instead of the colour blue, the colour black was chosen. The modified colour-concept Stroop test consisted of five tasks:- Colour Naming (CN), Easy-Object Colour-Naming (EO-CN), Difficult-Object Colour-Naming (DO-CN), Easy-Object Naming (E-ON) and Difficult-Object Naming (D-ON).

To select the easy and difficult to name stimuli two sets of twenty pictures were chosen. One set consisted of easy to name object pictures, and the other set consisted of difficult to name object pictures. The easy to name object pictures were the ones which were very familiar for children aged between four to five years. The difficult to name object pictures were the ones which were unfamiliar or unknown to children aged between four to five years.

These pictures were given to three speech language pathologists, three school teachers and three parents who interact with children between four to five years of age for validation. They were asked to evaluate the pictures for familiarity, colour suitability and ambiguity. The following three-point rating scale was used.

0-not appropriate; 1- more or less appropriate; 2-appropriate

A criterion of agreement of two out of three judges was followed. The targets selected for easy concepts were - yellow book, red shirt, green chair, and black shoe. For the difficult concepts - yellow kettle, red post-box, green cactus, and black anchor were chosen. The colours selected were yellow, red, green, and black.

Instead of using cards, the stimuli were presented through five sets of power-point slide-shows on a Dell laptop (screen width 14 inches by 7.8 inches). Each set started with a blank screen for 200ms, followed by a fixation cross of 500 ms. [15] The onscreen stimulus duration was 1.5 seconds. The background screen colour was grey.

Set1 - Colour Naming: Consisted of twenty patches of four colours yellow, red, green and black. The size of the colour patch was 1.75 by 1.75 inch. The order of the colours met the following criteria during presentation, a) all four colours appear equal number of times, and b) the adjacent patches were never of the same colour.

Set 2 - Easy-Object Colour Naming: Consisted of twenty pictures, five repetitions of four pictures - yellow book, red shirt, green chair, and black shoe. The pictures were presented in random order and followed the same restrictions that applied to set 1, that is, all four pictures appear equal number of times and the adjacent pictures were not the same. However, no picture could occupy the same position as that of its colour in the preceding set (e. g., yellow book could not appear in the same position as yellow had previously in set 1).

Set 3 - Difficult-Object Colour Naming: Consisted of twenty pictures, five repetitions of four pictures - yellow kettle, red post-box, green cactus, and black anchor. The pictures were presented in random order and followed the same restrictions that applied to set 1. However, no picture could occupy the same position

as that of its colour in the preceding sets 1 or 2 (e. g., yellow kettle could not appear in the same position as yellow had previously in set 1 or 2).
Set 4 - Easy-Object Naming: Consisted of the same four pictures taken for easy object colour naming task and arranged randomly but not similar to previous sets. Each picture was repeated five times and followed the same restrictions that applied to set 1.
Set 5 – Difficult-Object Naming: Consisted of the same four pictures taken for difficult object colour naming task and arranged in the same colour order as set 4. Each picture was repeated five times and followed the same restrictions that applied to set 1.

PHASE II
The experimental study
1) Participants

A total of 30 preschool children, 15 male and 15 female, mean age 4.6 years and 4.7 years respectively (range 4.3 to 4.11 and 4 to 4.9) were selected randomly from two English medium schools, in an urban area, for the study through purposive sampling technique. A written informed consent was taken individually from the parents of the children and a brief case history collected.

Only subjects with history of normal speech, language and motor development, between 4 to 5 years of age and attending English the medium schools participated. Uniformity of the mother tongue was maintained. The children came from families belonging to the middle social economic status. The children were screened for perception of the primary colours (yellow, red, green, and black).

2) Materials

The Colour-Concept Stroop power point slide show prepared in phase I. Assessment of Language Development (ALD) [16] was administered to ensure the age adequate receptive and expressive language development. Four colour cards were used to screen for the ability to discriminate, identify and name the colors yellow, red, green, and black.
For recording the verbal responses, *Praat* software (Version: 6.0.33 updated, 2017) was used and for the presentation of the stimuli, Dell laptop screen width 14 inches, with power-point windows 8 version.

3) Procedure

The testing was conducted in a private room. Each child was seated comfortably at a low table facing the laptop in a quiet and distraction free room. All sessions were audio recorded on Praat to obtain the reaction time. The experimenter sat beside the child and administered the tasks. Each task was demonstrated and practice trials were conducted to ensure that the instructions were understood. The power-point slide-show and the Pratt recording were started simultaneously with the word ‘start’, which was used to identify the stimulus-onset time.

Instruction

Task 1 (Colour Naming): "I am going to play some games with you. In the first game, we need to name the colours which appear on the laptop screen. First, I will take my turn, then, you take your”. At the end of the game, you can take any of these toys (sticker, colour pencil, rubber, whistle etc.)". Once the clinician had demonstrated the task the child did the practice trail following this Task1 was commenced.

Task 1 was followed by Tasks 2, 3, 4 and 5 with some modifications in the instructions for each task. For example, for Task 2 and 3 the instructions were as follows, “For this game, we need to name the colour of object and not the object on the laptop screen”. For Tasks 4 and 5, the instruction was, “For this game we need to name the object on the laptop screen”. For Task 5 the instruction was the same as that for Task 4 with the continuation, “If you don’t know the name of the object say what you think it may be or say ‘I don’t know’ ”. Each task was preceded with a demonstration and followed by a practice trial.

Statistical analysis

The responses were analyzed for the reaction time and tabulated. The following statistical procedure was employed:

i. Descriptive statistical analysis was used to compute the mean and standard deviation of the reaction time across for all tasks.

ii. Inferential statistics, the paired t-test was done to obtain the significance of the difference between the mean reaction time and mean interference for EO-CN and DO-CN.

RESULTS

Table 1: The mean and standard deviation (SD) of reaction times for Colour Naming (CN), Easy-Object Colour-Naming, Difficult-Object Colour-Naming (DO-CN), Easy-Object Naming (EO-N), Difficult-Object Naming (DO-N) across gender.

Sl No	Variabe	Gender	Colour Naming CN (secs)	Easy Object Colour Naming EO-CN (secs)	Difficult Object Colour Naming DO-CN (secs)	Easy Object Naming EO-N (secs)	Difficult Object Naming DO-N (secs)
1		M	1.305	1.762	1.352	1.293	2.002
2	Mean	F	1.306	1.788	1.359	1.291	1.882
3		Both	1.305	1.775	1.356	1.292	1.942
4	SD	M	0.044	0.099	0.060	0.060	0.255
5		F	0.057	0.133	0.069	0.070	0.135
6		Both	0.052	0.120	0.066	0.066	0.216

Table 1 shows that for the colour naming tasks the mean reaction times for EO-CN is the highest 1.77 secs (SD = 0.12), followed by the reaction time for DO-CN 1.35 secs (SD = 0.06), and finally by CN 1.3 secs (SD = 0.05).

The mean reaction time for EO-N and DO-N are 1.292secs and 1.942secs (SD = 0.06 and 0.21) respectively.

Table 2: The mean and SD of interference for Easy-Object Colour-Naming (EO-CN), and Difficult-Object Colour-Naming (DO-CN).

SL NO		EO-CN (secs)	DO-CN (secs)
1	Mean	0.47	0.05
2	SD	0.11	0.06

Table 2 shows the mean and SD of interference for EO-CN and DO-CN are 0.47 secs and 0.05 secs (SD = 0.11 and 0.06) respectively.

Table 3: The test of significance of difference between means for Reaction Time of Easy-Object Colour-Naming (EO-CN) and Difficult-Object Colour-Naming (DO-CN).

Variable	t	df	Sig 2tailed
EO-CN /DOCN	22.632	29	0.000*

*Significant at $p< 0.001$

Table 3 shows that the difference between the reaction times between EO-CN and DO-CN is significant on the paired t-test ($t = 22.623$, at $p<0.001$).

Table 4: The test of significance of difference of means interference for Easy-Object Colour-Naming (EO-CN) and Difficult-Object Colour-Naming (DO-CN).

Variable	t	df	Sig 2tailed
EO-CN /DOCN	-23.324	29	0.000*

*Significant at $p< 0.001$

Table 4 shows that the difference between the interference for EO-CN and DO-CN is significant on the paired t-test ($t = - 23.324$, at $p<0.001$).

DISCUSSION

The aim of the study was to investigate if conceptual depth would cause interference in a colour-concept Stroop task. The task involved the naming of the colour of two sets of pictures of objects, in which one set was easy to name and the other was difficult or unfamiliar. It was hypothesized that if the difference in reaction times between easy to name objects and difficult to name objects was significant then the hypothesis that the colour-concept Stroop interference paradigm has the potential to measure differences in conceptual depth or semantic representation holds true.

The results of the study confirm the hypothesis that it is possible to create a colour-concept Stroop paradigm where conceptual-depth acts as an interfering factor during object-colour naming tasks. The implication of this finding is that differences in reaction time signal differences in conceptual depth. That is, the Stroop interference effect can be used to measure of the differences in conceptual depth.

From the results we see that the easy to name objects were conceptually mature and triggered an automatic naming response during picture presentation for colour naming. Therefore, during the colour naming of easy objects the subject needed to inhibit the automatic object naming response and consciously name the colour of the object instead. The effort involved in inhibiting the automatic naming response increased the reaction time for naming the colour of the object. Thus, the automatic naming response of the familiar target caused interference.

In the case of unknown-objects or difficult-to-name objects the concepts are non-existent or still emerging. Therefore, for an unknown-object colour naming task a semantic representation is non-existent as a result there is no automatically triggered concept to interfere with the colour naming task, thereby, resulting in zero interference or shorter reaction time for colour naming. While in the case of a difficult-object whose concept is still emerging the semantic representation is too weak or fragile to result in interference as large as that for easy objects but may cause an interference that is larger than that for the unknown objects.

Thus, concepts that are fully formed produce maximum interference during object colour naming tasks and concepts that are in the process of emerging will cause less interference, while new or unknown concepts will cause no interference. These findings are consistent with the observation that the more meaningful a word the more interference it causes in studies involving semantic Stroop. [13, 14]

These findings have both clinical and research significance. The Stroop effect can be used to study individual differences in concept development within specific groups; to study rate of acquisition of concepts within and across specific groups; to measure progress in concept development in individuals undergoing treatment for language delays; to identify plateaus in concept development during language acquisition; to study factors which influence concept development and; to study rate of degradation of semantic concepts in persons with dementia.

The colour-concept Stroop can also be applied in forensic sciences to test for knowledge of truth during criminal investigations. Future studies can explore the validity of the same effect using words instead of pictures of objects in both children and adults.

CONCLUSION

In conclusion, the colour-concept Stroop paradigm is an effective means of measuring differences in conceptual depth and has significant clinical and research implications.

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How to cite this article: Varghese A, Jesuraja J. The colour-concept stroop effect- a measure of differences in linguistic conceptual depth. Int J Health Sci Res. 2020; 10(9):117-124.

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