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I affirm that this essay / lab report is my own work and does not include any unacknowledged material taken from another source.

Signed: Date:

Abstract

The Stroop effect is interference between automatic, involuntary processes and non-automatic, voluntary processes of the mind. This experiment measured reaction times when identifying the font colour of colour-name words which are displayed either in their own colour: congruent words, or else displayed in a different colour: incongruent words. An internet-based computer application was used, displaying a mixture of congruent and incongruent words on a monitor screen, the response mechanism being manual key strokes. The hypothesis that the reaction time would be significantly shorter for congruent words and significantly longer for incongruent words was supported by the results. This experiment supported the results of the classic Stroop effect experiment of 1935, although its design may have some implications for the labelling of keys or buttons for manual responses in future experiments.

The Stroop effect was named after J. Ridley Stroop's famous 1935 paper on interference in naming colours, but the field of research was at least fifty years old by the time Stroop performed his experiments.

Cattell (1886) found that reading a word was quicker than recalling and using the same word in a descriptive manner. He compared reaction times when reading the name of a colour compared to naming the colour of a printed square. His conclusions drew a distinction between automatic and voluntary processes: reading a word was automatic and therefore quick; deciding which descriptive word to use was slower because it was a "voluntary effort to choose the name".

Stroop was aware of the different nature of the associative bonds related to reading a word and naming a colour, and realised that he could offer a stimulus that had two different associative bonds. This stimulus could suggest two conflicting responses: the name of a colour printed in a different colour of ink could provoke the response of the word itself, or the colour of the ink (Stroop, 1935).

Stroop concluded that there was no significant increase in reaction time between reading aloud a colour-name word printed in black and reading aloud the same word printed in an incongruous ink colour. He did find a significant difference in reaction time between saying the name of the colour of printed squares, and naming the colour of ink an incongruous colour-name word was printed in.

Stroop referred to this effect as interference, and measured it in his participants over days of repetition, concluding that its effect declined or increased with practice or neglect, like any other learned skill.

The Stroop phenomenon is not just an interference effect; it can also facilitate the identification of a colour. Dalrymple-Alford & Budayr (1966) were the first to use congruent words in their tests as well as incongruent ones, but it was not until Sichel and Chandler (1969) that congruent, incongruent and neutral words (for instance 'xxxxxx') were used in the same test.

Sichel and Chandler established that congruent words and colours facilitated faster identification than a neutral word, and that incongruent words interfered with identification of the colour more than neutral words. The facilitation effect was generally of a lesser degree than the corresponding interference effect.

Both Dalrymple-Alford & Budayr and Sichel & Chandler used manually recorded times for a multiple of trials, speaking the name of the colour, and used paper materials, so any fumbling with papers, stammering words or tired fingers on the stopwatch may have adversely affected the results.

It should be noted that not all non-colour-name words are neutral in Stroop experiments. Klein (1964), Dalrymple-Alford (1968, 1972) and others have studied the extent to which the semantics of the word interfere or facilitate naming the colour, and have discovered that the closer the semantic association, the greater the effect, either facilitation or interference. The influence of semantically associated words on the Stroop effect is known as the Klein effect.

Redding and Gerjets (1977) tested Stroop effects using manual button pressing and vocal responses as their independent variables. They found that against vocal responses, interference was reduced and facilitation was increased in manual response trials.

McLain (1983) compared oral responses with button press responses where the buttons were either labelled with the colour-name word, or with a coloured label. McLain found that the degree of interference was smaller when using the word-labelled button than when responding vocally, and when using the coloured label buttons, there was no significant interference.

The hypothesis for this study is that when the word meaning is congruent with the colour of the word, reaction time will be enhanced. When the word meaning and the colour of the word are incongruent, then reaction time will be impaired.

Method

Design

The experiment used repeated measures, all of which were undertaken by the same participants, pressing a particular computer key to signify the colour in which a word is displayed on a computer screen. The words were the names of colours, but the displayed colours were not necessarily congruent with the meaning of the words. The experiment featured both congruent and incongruent stimuli in seemingly random combinations

The independent variable was the congruence or incongruence between the displayed colour of the word and the semantic meaning of the word itself. The dependent variable was the reaction time between the word appearing on the screen and it being identified correctly by the participant.

The data collected was on a ratio scale.

Participants

The participants were approximately 140 second-year psychology undergraduates from the University of Strathclyde, who took part as a requirement of their course.

Materials

The experiment was conducted using an internet-based computer application developed by Doctor Mark Tew and Doctor Ken McGraw at the University of Mississippi. The application was written using Macromedia Shockwave, which runs autonomously on the client computer and therefore has no network or internet time-lag.

All the participants used very similar if not identical IBM-compatible computers, with fourteen to fifteen inch cathode ray tube monitors displaying the program, and standard alphanumeric keyboards to register their input. The experiment was conducted in a well-lit and occasionally busy computer laboratory at the University of Strathclyde, between three and five p.m. over several days.

Procedure

After navigating to the appropriate experiment page and giving consent for the experiment, the participants were asked to enter their gender and age.

The instructions read: “In this experiment you will be shown a flashing plus sign (+) that will be followed by a quick, vertically oriented display of a color word (blue, green, red or yellow). The word will be either congruent in meaning and color (e.g. ‘RED’ printed in red) or noncongruent (e.g. ‘RED’ printed in blue).In either case, your assignment is to indicate as rapidly as possible the **color of the word** using the keys on the number pad.”

Participants then undertook a practice session, identifying solid coloured blocks, and having reached an appropriate level of competence with the keypad, they were allowed to continue to the experiment.

Participants pressed a key to start the experiment, and when the plus sign disappeared and the word flashed on the screen, they pressed the key labelled with the colour corresponding to the font colour of the word. The on-screen key ‘legend’ was labelled both by name and by colour, and did not appear until the word had been displayed. This process was repeated 72 times. The vertically-oriented words appeared in one of three positions: left, right or centre of the window. Incorrect responses were ignored; the time until the correct colour was selected was recorded. At the end of the experiment, the host computer automatically sent the reaction time data to the University of Mississippi web server.

It should be noted that not all the available variables in this experiment were included as part of this study. None of the gender, age, word position differentiation or incorrect response information gathered was used.

Results

The results shown here are based on the mean reaction times for both congruent and incongruent words, taken from a sample of thirty participants (appendix A).

The congruent word reaction time had a mean value of 0.942 seconds, standard deviation 0.176. The incongruent word reaction time had a higher mean value of 1.353 seconds, standard deviation 0.26. Neither scale displays a significant skew. The ranges of scores are 0.66 seconds for congruent words and 1.02 seconds for incongruent words. The data are of a ratio scale.

A related t-test returned a value of -8.063 with 29 degrees of freedom, which is significant at the 1% level ($t(29)=18.063$, $p<0.0005$). The calculations were performed on SPSS for Windows v11.5 (see appendix B).

Figure 1: Incongruent Reaction Times

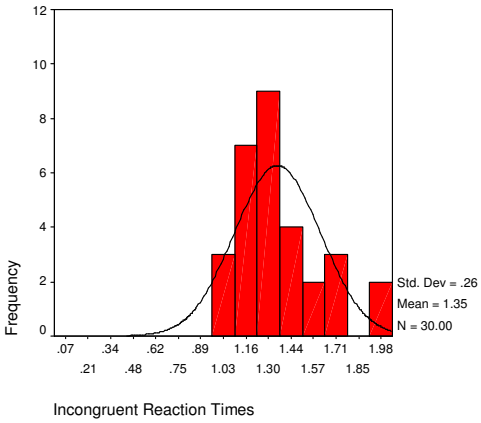


Figure 2: Congruent Reaction Times.

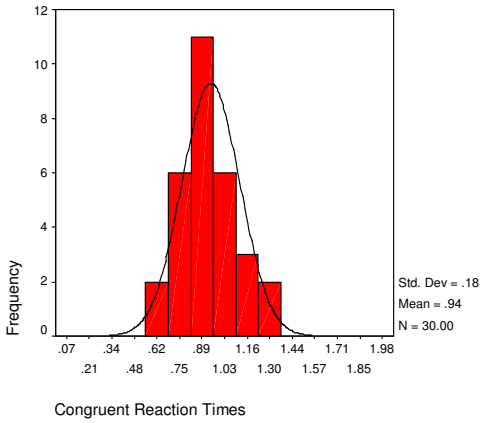
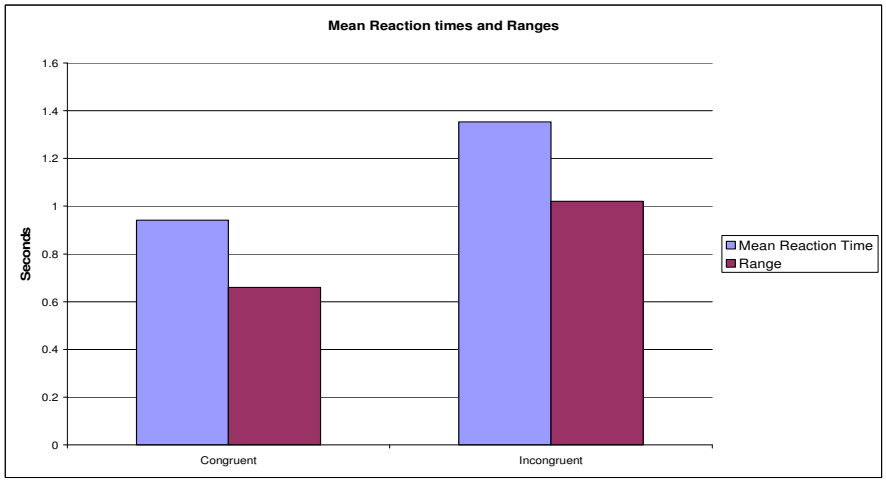


Figure 3: Mean Reaction Times and Ranges



Discussion

The results of the experiment support the alternative hypothesis that when the word meaning is congruent with the colour of the word, reaction time will be enhanced, and when the word meaning and the colour of the word are incongruent, reaction time will be impaired.

The results support Stroop's findings about the incongruity of word and colour causing interference in the naming of the colour. The reaction time for incongruent word and colour combinations was significantly larger than the reaction time for congruent words and colours, even though the orientation and position of the displayed words differed from the original experiment. Stroop also used black fonts instead of congruent-coloured fonts as his other independent variable, and vocal instead of manual responses were utilised as dependent variables.

Dalrymple-Alford and Budayr's results were also supported, probably more accurately than Stroop's, since this experiment used congruent and incongruent words and colours. The manual response instead of a vocal response is, however, different, although the computer environment, which was not widely available in 1966, may have positively affected the accuracy of the reaction times obtained.

It is not conclusive whether Sichel and Chandler's results were supported, because there was no 'neutral word' independent variable to judge by. Their results were partly supported: the congruent reaction times were significantly shorter than the incongruent reaction times, but without a neutral word variable, the comparative aspects of interference and facilitation cannot be evaluated.

Similarly, Redding and Gerjets conclusions about reduced interference and increased facilitation using button pressing instead of vocal responses are inconclusive in this experiment, because of the lack of a vocal response time independent variable.

McLain's findings regarding the labelling of buttons were not supported by this experiment, but produced an interesting observation. The labels in this experiment were both coloured and over-written with the colour-name word. McLain reported that coloured labels instead of words produced no significant interference in a colour naming task. This does not help to explain why, in this experiment with coloured labels, significant interference was observed, unless the word on the label in some way interfered with the mental comparison of colours between the experimental word and the on-screen label. This may, or may not, be due to the congruity or incongruity of the experimental word and the word on the label.

For example, if the experimental stimulus 'RED' appears in a blue font colour, the participant will look for the key label that corresponds to the colour blue. This label will have the word 'BLUE' on it, and the red label will have the word 'RED' on it. McLain reported that coloured key labels produced no significant interference, presumably because the colours were mentally compared directly without any word-recall task. If McLain is correct, interference observed in this experiment may be due to the incongruity of the two words 'RED' and 'BLUE', either simply because the words are incongruent, or because the word 'RED' also appears on another label which the participant has just looked at, creating a dilemma as to which one to choose.

This observation, if nothing else, supports Cattell's assertion that reading is an automatic process which cannot be avoided.

To further confuse things, in order to maintain a readable contrast against the coloured label, some of the label words appeared to be displayed in incongruent colours (i.e. not black or white) which may have interfered with the responses.

This experiment revisited the Stroop effect with more advanced and accurate experimental techniques than Stroop enjoyed in the nineteen thirties. The computer and internet-based resources utilised may not have been specifically designed for this experiment, but the result still strongly supports Stroop's original

findings that a colour name displayed in an incongruent colour will cause interference and slower reaction times.

There have been many variations and improvements on Stroop's original experiment, including using manual responses instead of vocal, using congruent colour-word stimuli instead of neutral ones, both of which were adopted by this experiment.

There is some ambiguity over the labelling of the colour keys to register responses, which may be an area for further research to establish whether having words on the key labels of colour-word Stroop experiments causes interference, and in what way.

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Appendices

Appendix A: Participants' mean reaction times.

Participant	Congruent	Incongruent
1	.75	1.24
2	.89	1.27
3	.65	1.07
4	.87	1.68
5	.95	1.34
6	.80	1.10
7	1.00	1.01
8	1.11	1.11
9	1.09	2.03
10	1.00	1.07
11	.75	1.10
12	.85	1.24
13	.90	1.45
14	1.08	1.64
15	1.21	1.46
16	.76	1.33
17	.65	1.25
18	1.06	1.23
19	.95	1.11
20	.93	1.10
21	.72	1.26
22	.87	1.66
23	.92	1.35
24	1.06	1.44
25	1.31	1.10
26	1.26	1.54
27	1.22	1.46
28	.95	1.92
29	.75	1.35
30	.95	1.68

Appendix B: SPSS Calculations.

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std.	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
CONG	30	.66	.65	1.31	.9420	.0321	.17590	.031	.301	.427	-.482	.833
INCONG	30	1.02	1.01	2.03	1.3530	.0475	.26028	.068	.920	.427	.401	.833
Valid N (listwise)	30											

Paired-Samples T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	CONG	.9420	30	.17590	.03211
	INCONG	1.3530	30	.26028	.04752

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	CONG & INCONG	30	.226	.229

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	99% Confidence Interval of the Difference Lower	Upper			
Pair 1	CONG - INCONG	-.4110	.27919	.05097	-.5515	-.2705	-8.063	29	.000