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BILINGUALISM AND PROCESSING OF ELEMENTARY COGNITIVE TASKS BY CHICANO ADOLESCENTS

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Abstract

The results of two experiments are presented. In Experiment 1, Chicano adolescents, classified as balanced, proficient bilinguals (fluent English-Spanish speakers) or non-balanced bilinguals English-dominant speakers possessing little Spanish mastery) were administered Hick's (1952) sensory~perceptual memory task. While both language groups exhibited classic increases in reaction time (RT) with increased cognitive complexity of the task' there was no difference in RT attributable to differences in bilingual proficiency. This finding indicates that if there is an interaction between bilingual proficiency and rate-of-cognitive-information processing, it does not occur at the level of sensory-perceptual memory. In Experiment 2, the participants were administered Sternberg's (1969) digit-span, short-term memory task. Both groups showed increased RT with increased digit span. However, RT of the non-balanced group was significantly faster overall than the RT of the balanced, proficient group, indicating that an interaction between bilingual proficiency and rate-of-cognitive-information processing initially occurs at the level of short-term memory. However, there was no difference in the number of correct and incorrect responses between the two language groups. Some possible explanations for the difference in rate-of-information processing between the two language groups on the short-term memory task are presented.

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Psychometric research conducted over the last three decades provides convincing evidence that bilingualism has a positive effect on cognitive processing. It is now generally accepted, for example, that bilinguals who have achieved a high level of proficiency and balance in their home language (L1) and second language (L2) outperform monolinguals on verbal and nonverbal measures of intelligence as well as demonstrate greater cognitive flexibility than their monolingual counterparts on tasks requiring complex problem-solving skills (see Náñez, Padilla, & López-Máez, 1992 for a current review of this literature).

A considerable literature now exists regarding the relationship between bilingualism and performance on complex cognitive tasks. However, little is known about how bilingualism affects processing of simple, "elementary" cognitive tasks that can be measured with time as a very precisely controlled dependent variable. Tasks of this type tap basic cognitive processes involving sensory-perceptual memory, short-term memory, and/or long-term memory, as opposed to conventional tests of intelligence such as the Stanford-Binet, which tap complex cognitive processes involving feedback, reflection, mental representation, and other metacognitive skills. Durán & Enright (1983), Náñez, Padilla, & López-Máez (1992), and Náñez & Padilla (1993) have proposed chronometric, information processing methodology as particularly well-suited for conducting this type of research. However, to date, such methodology has been applied almost exclusively to studying the correlation between reaction time (RT) to elementary cognitive tasks and psychometric IQ in Anglo samples. For example, Anglos exhibit a linear increase in RT with increased cognitive uncertainty on a variety of RT tasks, such as Hick's sensory-perceptual task (Hick, 1952; Jensen & Munro, 1979; Jensen, 1979, 1980, 1982; Small, Raney, & Knapp, 1987), short-term memory digit-span tasks (Sternberg, 1966; Vernon, 1983; Vernon & Jensen, 1984) and long-term memory sentence verification tasks (Vernon, 1983; Vernon & Jensen, 1984).

The Hick paradigm is now well-established as a reliable measure of rate-of-information processing for simple and choice reaction time (sensory-perceptual) tasks. The Hick paradigm is a reaction time task that involves depressing a home button, monitoring a set of lit buttons ranging from one to eight in number, and lifting the index finger off the home button to press the button that turns off. The buttons are situated in a semicircle around the home button and are easily monitored by focusing one's gaze on the two center buttons. Because the task of monitoring the buttons is so effortless, it is the

closest approximation for measuring pure reaction time available to researchers.

Numerous studies (e.g. Jensen, 1979, 1980, 1982; Jensen & Munro, 1979) have demonstrated that subjects varying on characteristics such as psychometric IQ exhibit Hick-type increases in RT with increased cognitive uncertainty or cognitive load. However, to date, this methodology has been utilized almost exclusively with Anglo populations and has seldom been used to study RT in other ethnic and racial groups. Thus, according to Náñez and Padilla (1993), "...it is advisable to determine whether it applies to Chicanos" and "...for both scientific and ethical reasons, it is imperative to establish a priori, the population generalizability or ecological validity of this research paradigm before applying it to a population previously untested with the paradigm" (p. 500).

Recent research (Náñez & Padilla, 1993) addressed this concern and provides evidence that, like their Anglo counterparts, the RTs of Chicano adolescents in general (i.e., when bilingualism is not considered) conform to Hick's law. This law holds that RT increases linearly as a function of the number of bits or units of information to be processed in simple or choice reaction time tasks. Furthermore, it indicates that a negative correlation exists between RT across bits and psychometric IQ as measured by standardized IQ tests. In the present study, two experiments were conducted utilizing chronometric methodology to expand information processing research to the study of cognitive processes when bilingual proficiency and balance are considered as independent variables. Rate-of-information processing was compared between Chicano adolescents who were classified as either balanced, proficient bilinguals (fluent English-Spanish speakers) or non-proficient bilinguals (English-dominant individuals possessing little mastery of Spanish). RT between the two language groups was recorded on Hick's (1952) sensory-perceptual memory paradigm (Experiment 1) and Sternberg's (1969) short-term memory, digit-span paradigm (Experiment 2), in order to initiate research investigating the relationship between bilingualism and rate-of-information processing of elementary cognitive tasks.

Experiment 1

The purpose of Experiment 1 was to examine whether the initial interaction between bilingualism and cognitive processing occurs at the level of sensory-perceptual memory.

Method

Participants

Forty-nine 15- to 17-year-old Chicano adolescents (18 males and 31 females) participated in this study. The subjects were high school students attending an urban southwestern high school or math, science, or engineering enrichment programs held during the summer at a large southwestern university.

Materials and Apparatus

The Raven Advanced Progressive Matrices Set I (Raven, 1958) and Set II (Raven, 1976) were administered to assess psychometric IQ. The English and Spanish versions of Duncan and De Avila's (1969) Language Assessment Scales-Oral (LAS-O) were administered to independently assess proficiency in each of the two languages. The reaction time apparatus consisted of a version of Jensen and Munro's (1979) subject's console designed to measure the subjects' reaction time in ms, to a simple reaction time (SRT) task and choice reaction time (CRT) task. The console was interfaced with a Zenith PC equipped with an electronic timer. (See Jensen [1985] or Náñez & Padilla [1993] for a detailed description of the console.)

Procedure

All testing and participant observations were conducted by proficient English-Spanish bilingual, Chicano investigators. The LAS-O was administered on an individual basis, with the subject's verbal story re-telling responses transcribed and scored off audio tape. All participants were classified as "fluent" (proficient) English speakers, as determined by their scoring at levels 4 and 5 on the English LAS-O. The participants were divided into two language groups based on their Spanish fluency proficiency scores. Those scoring at levels 4 and 5 of the Spanish LAS-O were assigned to a "balanced, proficient bilingual" group (n = 29). Those scoring at levels 1 and 2 on the LAS-O were assigned to a "non-balanced" (low Spanish proficiency) group (n = 20).

Set I of the Raven Advanced Progressive Matrices was utilized to familiarize the participants with the test and testing procedures. Five minutes were allotted for completing the test. The proctor then read the correct answers and each subject scored his or her own test. This was done to provide

immediate feedback and to answer any questions concerning the test or testing procedure raised by the participants. The participants were then administered Set II of the Raven Advanced Progressive Matrices with no time limit imposed. All participants completed Set II in less than one hour. In order not to confound the effects of IQ with language proficiency and balance, psychometric IQ was matched at a high level by including in the study only participants scoring above the 90th percentile for their age-normed group on Set II of the Raven.

In the Hick paradigm, the participant depresses a "home" button on a panel, which, after a random interval of 0 to 2 seconds, results in the turning off of one of eight lit buttons located in a semi-circle equidistant from the home button. The participant's task is to lift his or her index finger from the home button and press the unlit (target) button as quickly as possible. The target button is relit as soon as it is pressed. The time required by the participant to lift his or her index finger off the home button after a button has been turned off is taken as an index of the time required to process the task. Cognitive uncertainty in this task increases incrementally from monitoring and responding to one test button (0 "bits" of information) to monitoring and responding to two, four, and eight buttons (1, 2, and 3 bits of information) respectively.

Results and Discussion

Regression analyses revealed that both language groups exhibited classic Hick-type increases in RT with increased cognitive uncertainty or bit size (Figure 1). The slope of the regression line for the balanced, proficient language group was 14.84 ms, with an intercept of 366.63 ms. For the non-proficient group, the slope and intercepts were 12.62 and 368.98 ms respectively. The amount of variance in RT accounted for by the regression lines were virtually identical, multiple R squared = .951 for the balanced, proficient group and .955 for the non-balanced group.

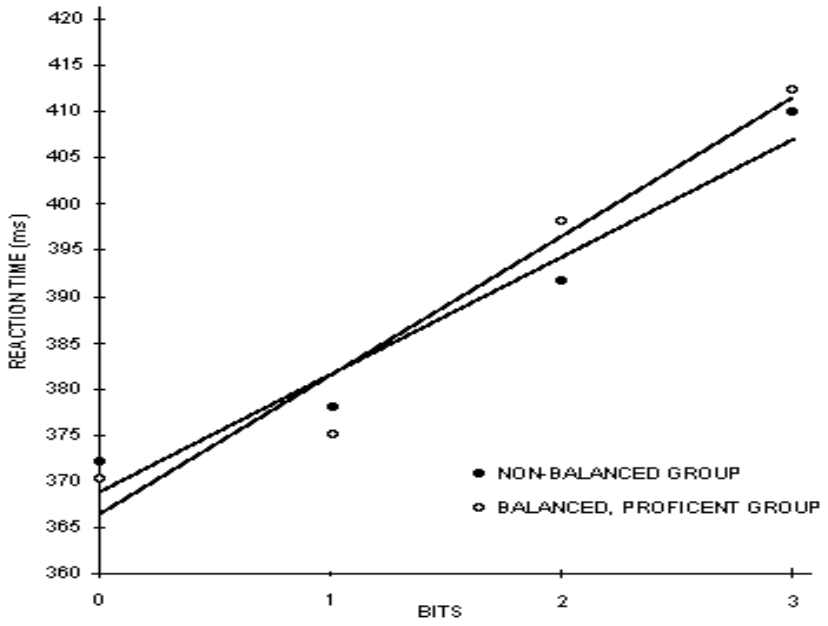

Figure 1. Regression of RT across bits for balanced, proficient and non-balanced language groups

A 2 (Language Group: balanced, proficient group vs. non- balanced group) X 4 (Bit Size: 0, 1, 2, 3 bits) ANOVA revealed a significant main effect for the Bit Size variable, attributable to the linear increase in RT exhibited by both language groups. The main effect for the Language variable and the Language Group X Bit Size interaction were not statistically significant.

The finding that both groups exhibited a significant increase in RT with increased cognitive load supports Náñez and Padilla's (1993) reasoning that information processing methodology is appropriate for studying cognitive processes in Chicanos. Also, no evidence was found that differences in bilingual proficiency and balance produce differences in rate-of-information processing at the level of sensory-perceptual memory processing.

Experiment 2

In Experiment 2, the interaction between bilinguality and cognitive processing was examined at the level of short-term memory (STM). Sternberg (1969) digit-span task was utilized in order to explore whether the initial interaction between bilingual proficiency and rate- of- cognitive-information processing occurs at the level of STM.

Method

Participants

The participants were 48, 15- to 17-year old Chicano adolescents (18 males, 30 females) drawn from the same subject pools as the participants in Experiment 1.

Apparatus

The participants were administered the Spanish and English versions of the LAS-O and Sets I and II of the Raven Advanced Progressive Matrices in the same manner as in Experiment 1. In the RT task a Zenith PC was interfaced with the response console in order to record RT in ms. The console contained a home button and two response buttons situated in an inverted triangle fashion with the home button constituting the apex of the triangle (see Jensen, 1985.)

Procedure

The participants were classified as balanced, proficient bilinguals (n = 28) or non-balanced bilinguals (n = 20) as in Experiment 1. A slight variation of Sternberg's (1969) STM, digit-span task was administered to the subjects. The task differed from Sternberg's only in that the RT stimuli were presented on a computer monitor as opposed to a binary response console.

When ready to initiate a test session, the participant was instructed to press the home button with his or her index finger. Soon after the home button was depressed, a single test digit or digit set ranging from 2 to 7 digits in length appeared on the computer monitor for several seconds. This phase was followed immediately by a single probe digit. The participant's task was to respond by lifting his or her index finger from the home button and pressing the "yes" button if the probe matched the test digit or was contained within the test digit set. If the probe did not match the test digit or was not contained within the test digit set, the participant pressed the "no" button on the console.

RT consisted of the number of ms transpiring from presentation of the probe digit to lifting the finger off the home key. Each participant saw a total of 84 trials (12 trials per digit set size), with digit set size varying randomly from 1 to 7 digits between trials. The percentage of correct and incorrect responses across trials was also recorded.

Results and Discussion

Regression analyses revealed an overall increase in RT with increased digit span (Figure 2). The slope of the regression lines were 31 ms and 25 ms, while the intercepts were 521 ms and 484 ms for the balanced, proficient and non-balanced groups respectively. The amount of variance in RT accounted for by the regression lines was similar, multiple R squared = .975 for the P balanced, proficient group and .943 for the non-balanced group.

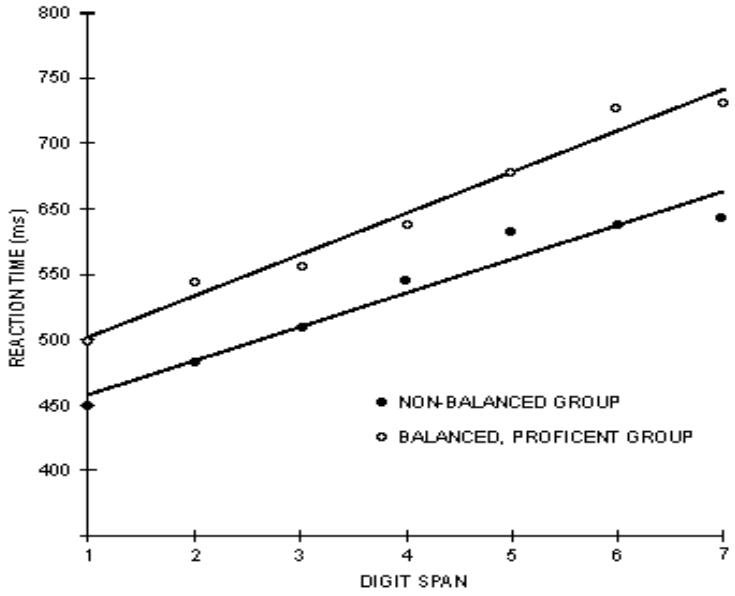

Figure 2. Regression of RT across digit-span for balanced, proficient and non-balanced language groups

A 2 (Language Group: balanced, proficient group vs. non- balanced group) X 7 (Digit Span: 1, 2, 3, 4, 5, 6, 7 digits) MANOVA revealed a significant main effect for Language Group, with the non-balanced group exhibiting faster average RT than the balanced, proficient group across digit set size. The main effect for Digit Span was also significant, with both language groups showing an overall increase in RT with increasing digit set size. The Language Group X Digit Span interaction was not significant. While the non-balanced group proved to be faster on average than the balanced, proficient group, there was no difference in the number of correct and incorrect responses between the language groups. Both groups performed with a high degree of accuracy. The average number of correct responses was 81.40 (96.90%) and 81.39 (96.89%) out of the total 84 responses for the non-balanced and balanced, proficient groups, respectively. Given the fact that the digit-span task utilized in Experiment 2 was a relatively simple one, failure to detect differences in the number of correct responses between the two language groups may affect reaction time, but not response accuracy. Future research comparing the performance of groups differing on language balance and proficiency on more cognitively demanding reaction time tasks should reveal which is the case.

General Discussion

Recent research revealed that the Hick paradigm is appropriate for studying cognitive information processing in Chicano adolescents (Náñez & Padilla, 1993). The purpose of the present study was to apply chronometric information processing methodology to begin the investigation of whether an interaction exists between bilingual balance and proficiency and rate-of-cognitive-information processing, and if so, where within the information processing continuum the initial interaction occurs and what might that interaction be like.

Experiment 1 showed that Chicano adolescents' RT to the Hick paradigm conform to Hick's Law, with both language groups showing similar slopes and intercepts when their RT was regressed across bits. It appears that differences in bilingual proficiency and balance do not produce differences in rate-of-information processing at the level of sensory-perceptual memory. The probable reason for this finding is that the Hick task requires little or no cognitive load to perform. The participant is merely required to monitor a set of lights and make a response immediately after one of the lights has been

turned off. Thus, Experiment 1 replicated Náñez and Padilla's (1993) findings, and also served to establish a baseline within the information processing continuum from which to begin investigating the interaction between bilingualism and cognitive processing.

From the perspective of an "information processing continuum" Náñez, Padilla, & López-Máez, 1992), STM tasks, such as the digit-span task utilized in Experiment 2, lie on the continuum between sensory-perceptual processing and long-term memory processing. Experiment 2 adds to our knowledge of the interaction between bilingualism and cognitive processes, by demonstrating that bilingualism initially affects cognitive processing at the level of STM. Also, while differing degrees of bilingual competence may affect the rate with which a STM task is processed, it docs not produce differences in the accuracy of subjects' responses.

The balanced, proficient bilingual may require a little more time to complete elementary cognitive tasks with the same accuracy as his or her non-proficient counterpart. Future research should help clarify why this is so. Must proficient bilinguals "scan" a larger memory store than non-proficient bilinguals and monolinguals, which would naturally require more time to conduct? Must proficient bilinguals check their decisions for accuracy in both languages before making a response? Does this finding mean that proficient bilinguals should be allowed more time than non-proficient bilinguals and monolinguals to complete timed tests, and if so, what might be the "optimal" time ratio?

There are a number of other interesting questions which remain to be explored. A logical follow-up to the present study should investigate whether the findings of Experiment 2 hold for cognitive tasks requiring long-term memory (LTM) processes to perform. The "sentence verification technique" (SVT), in which the individual must remember the relationship between a set of relational terms for a short period of time and respond to whether or not a probe statement represents the relationship depicted in the test statement constitutes such a task.

The interaction between bilingual ability and cognitive processing also needs to be explored at higher levels of cognitive complexity. For example, experiments should be conducted that require participants to respond to a combined digit-span plus SVT task. In this case, the participant is presented a digit or set of digits as in the standard digit-span task, followed by interjecting a SVT task, to which the participant must respond before the probe digit is presented. This task is more cognitively demanding than the

SVT task alone, because it requires the participant to process and store the test digit(s) in LTM while solving the SVT task and subsequently retrieving and transferring the stored digit(s) into STM to respond to the probe digit. The cognitive load at this level of information processing is considerably greater than at the level of STM, constituted by the digit-span task. Would the relationship between RT and bilingual proficiency and balance found in Experiment 2 of the present study be maintained or would the increased demand for cognitive power and flexibility of the proposed task counter the speed advantage of the non-balanced bilingual relative to the balanced, proficient bilingual?

A set of studies requiring participants to engage in a variety of complex cognitive and problem-solving tasks under timed and untimed conditions would also be informative. Research shows that a participant's performance is poorer when required to complete psychometric tests such as the Raven Progressive Matrices under timed vs. untimed conditions. The same has been found when participants perform SVT type tasks in the weaker of their two languages (Durán & Enright, 1983). If substantiated, such findings would produce convincing evidence that a probable "cost" or trade-off to the balanced, proficient bilingual's advantage in cognitive flexibility on complex cognitive tasks is a decrease in speed of information processing of elementary cognitive tasks. If this turns out to be the case, future research should address issues of what this trade-off means for the bilingual student in applied classroom settings or other formal learning and problem-solving situations.

References

Duncan, S. E., & De Avila, E. A. (1969). Language Assessment Scales (LAS). San Rafael, CA: Linguametrics Group.

Durán, R., & Enright, M (1983). Reading comprehension proficiency, cognitive processing mechanisms, and deductive reasoning in bilinguals. Final Report (grant no. NIE-G-80-O 157). Princeton, NJ: Educational Testing Services.

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology, 4*, 11-26.

Jensen, A. R (1979). Outmoded theory or unconquered frontier? *Creative Science Technology, 2,* 16-29.

Jensen, A. R (1980). Chronometric analysis of intelligence. *Journal of Social and Biological Structure, 3,* 103-122.

Jensen, A. R. (1982). Reaction time and psychometric g. In H. J. Eysenck (Ed.), *A model for intelligence* (pp. 93-132). New York: Springer-Verlag.

Jensen, A. R. (1985). Methodological and statistical techniques for the chronometric study of mental abilities. In C. R. Reynolds & V. L. Wilson (Eds.), *Methodological and statistical advances in the study of individual differences.* New York: Plenum, 1983.

Jensen, A. R., & Munro, E. (1979). Reaction time, movement time, and intelligence. *Intelligence, 3,* 121-126.

Náñez, J. E., & Padilla, R.V. (1993). Processing of simple and choice reaction time tasks by Chicano adolescents. *Hispanic Journal of Behavioral Sciences, 15* (4), 498-508.

Náñez, J. E., Padilla, R. V., & López-Máez, L. (1992). Bilinguality, intelligence, and cognitive information processing. In R.V. Padilla and A.H. Benavides (Eds.), *Critical perspectives on bilingual education research* (pp. 43-69). Tempe, AZ: Bilingual Press/Editorial Bilingüe.

Raven, J. C. (1958). *Advanced Progressive Matrices.* Set I. London: H.K. Lewis & Co. Ltd.

Raven, J. C. (1976). *Advanced Progressive Matrices.* Set II. Oxford: Oxford Psychologists Press.

Small, M. A., Raney, F. J., & Knapp, T. 3. (1987). Complex reaction time and general intelligence: A refinement. *Journal of Genetic Psychology, 148* (4), 405-414.

Sternberg, S. (1966). High speed scanning in human memory. *Science, 153*, 652-654.

Sternberg, 5. (1969). The discovery of processing stages: Extension's of Donder's method. (Attention and performance II). *Acta Psychologica, 30,* 276-315.

Vernon, P. A. (1983). Speed of information processing and general intelligence. *Journal of Educational Psychology, 7,* 53-70.

Vernon, P. A., & Jensen, A. R. (1984). Individual and group differences in intelligence and speed of information processing. *Personality and Individual Differences, 5,* 411-423.