Psicológica (2010), 31, 199-217.

Summation in predictive learning in children

Felipe A. Cornejo (1), Ramón D. Castillo (1), María A. Saavedra (2) & Edgar H. Vogel* (1)

(1) Universidad de Talca, Chile; (2) Universidad de Chile, Santiago, Chile

Considerable research has examined the contrasting predictions of configural and elemental associative accounts of learning. One of the simplest methods to distinguish between these approaches is the summation test, in which the associative strength of a novel compound (AB) made of two separately-trained cues (A+ and B+) is examined. The configural view predicts that the strength of the compound will approximate the average strength of its components, whereas the elemental approach predicts that the strength of the compound will be greater than the strength of either component. The summation test has lead to contradictory evidence in experiments with animals as well as with human adults. The purpose of this research was to examine summation in predictive learning of 5- 9 years old children. The results provided evidence of summation (i.e., AB greater than A and B) after training with a "simple summation" procedure (A+ B+ test with AB; Experiment 1, n=26); but no summation following a "preserved conditioned inhibition" procedure (i.e., A+ B- AB- followed by B+; and test with AB; Experiment 2, n=26). In Experiment 3, both effects were simultaneously observed (n=14). These results are consistent with reported findings in both Pavlovian conditioning with animals and predictive learning with adult humans. Theoretical alternatives within the elemental and configural approaches are discussed.

One issue that has been subject to considerable debate among learning theorists is the nature of the effective representation of stimuli participating in associative learning. This debate is especially vivid in the domain of Pavlovian conditioning, when the association between an Unconditioned Stimulus (US) and a Conditioned Stimulus (CS) formed by several stimuli,

---

* Acknowledgments: This work was supported by grants from Fondecyt Nº 1060838 to E. H. Vogel and from the University of Talca to the Program of Research on Quality of Life (Res. 387/2007). Correspondence: Edgar H. Vogel. Universidad de Talca. Escuela de Psicología. Casilla N° 747. Talca, Chile. Tel: (5671) 201565. Fax: (5671) 201510. E-mail: evogel@utalca.cl

is compared to the association acquired by each of its components. Basic elemental theories (e.g., Rescorla and Wagner; 1972), assume that stimuli are processed separately, independent of whether they have been presented alone or compounded with other stimuli, meaning that the representation of a stimulus set is equivalent to the sum of the representations of each element.

Alternatively, basic configural theories assume that compound stimuli are processed as unique exemplars that form associations independently of those formed by their elements. For example, Pearce (1994, 2002) proposed a model that assumes that configurations develop unitary associations with the US and that their component elements only play a role in determining the degree of generalization between configurations.

Although the elemental and configural approaches have been described in opposition to one another, it is important to appreciate that both can be described in terms of elemental processes. Brandon, Vogel and Wagner (2000) emphasized that the principal difference between the two approaches could be appreciated in the operation of the model when a compound is formed by stimuli that have been presented separately. The elemental view always assumes a summation of associative strengths of the components forming a new compound, whereas the configural approach always assumes a subtraction of the associative strength of an element when it is presented in companion with another cue.

Several experiments have been conducted to examine the contrasting predictions of configural an elemental approaches with respect to stimulus compounding.

For example, the elemental approach predicts a summation of responding to two stimuli trained separately and tested in compound (training A+; B+; testing AB) while the configural approach predicts an "averaging" of the degree of responding to the elements. The prediction of the elemental model is additive because each element contributes its whole associative strength when forming a compound with another stimulus. By contrast, according to the subtractive principle of the configural approach suggested by Pearce (1994), each stimulus contributes only half of its associative strength when forming a compound, since each is only 50% similar to the compound AB.

With respect to the simple summation procedure, the literature in classical conditioning is controversial. For example, several studies conducted with rats and rabbits, generally using as CS's different modalities (e.g., visual, tactile, auditory), have found evidence of summation, supporting the elemental approach (e.g., Rescorla, 1997; Whitlow and

Wagner, 1972). On the contrary, absence of summation has been found in studies using pigeon autoshaping and visual stimuli (e.g., Aydin and Pearce, 1995). In human predictive learning there have been a few reports of summation (Collins and Shanks, 2006; van Osselaer, S, Janiszewski and Cunha, 2004; Soto, Vogel, Castillo and Wagner, 2009).

In addition to these experiments with simple summation, more complex tasks have been performed encountering the same level of ambiguity. One of them is the so-called "preserved conditioned inhibition" procedure, in which training with A+ AB- is followed by B+, before testing A, B and AB. According to the elemental view, the initial training results in A developing an excitatory association with the US and B an inhibitory association that counteracts the effect of A in the AB compound. In the second phase of training with B+, the elemental approach predicts that B gains excitatory association with the US (or looses some of its inhibitory association), so that AB becomes greater than A and B by themselves (summation). On the other hand, the configural view predicts that in the first phase A develops an association with the US and AB does not, and that the excitatory learning accrued to B in the second phase leaves relatively unaffected the original value of AB, so that responding to AB should be less than that to A and B in the final test (no summation). Using this procedure, there have been some reports favouring either the configural approach (Pearce and Wilson, 1991) or the elemental approach (Kudney and Wagner, 2004).

There have been some efforts to explain these discrepancies (Myers, Vogel, Shin, & Wagner, 2001; Melchers, Shanks & Lachnit, 2008), but the controversy is still not solved. The predominant idea at present is that codification of stimuli involves configural as well as elemental processes, and that the predominant strategy could dependent on such variables as stimulus modality, task type, and individual differences. Therefore, researchers have become interested in the specific conditions determining one or the other type of processing and have begun to develop flexible models that may allow for such alternate processing (Wagner, 2003).

The nature of such a flexibility of processing deserves to be evaluated systematically in different tasks, subjects and experimental procedures. The literature is showing incipient signs, such as the observation that for the same kind of learning task it is possible to obtain "configural" or "elemental" solutions by varying subject's previous experience with other problems requiring "elemental" or "configural" solutions (Williams & Braker 1999). Others have suggested that stimulus characteristics are the critical variable explaining the type of processing employed. For example, Lachnit (1988) demonstrated that configural or elemental processing can be obtained in a summation task, depending on whether the compound stimuli belonged to integral or separable dimensions, respectively (Garner, 1974).

Another possibility is that the type of processing depends, at least partly, on the individual characteristics of the experimental subjects. For instance, it has been suggested that the ability to perceive separated elements in a compound stimulus may develop with age (Aslin & Smith, 1988; Burns, 1986). According to this view, younger children perceive as a configuration the same stimulus that adult perceive as an aggregation of elements. There is no a clear-cut age for the configural-to-elemental shift in processing, but some studies with classification tasks have suggested that five years old children are more likely to use a configural strategy than at the age of seven (Smith and Kemler, 1977). To our knowledge, no studies have been conducted on this issue with predictive learning in children, so the present research focused on it.

Experiments 1 and 2 examined simple summation and preserved conditioned inhibition, respectively in groups of 4.5-5.5 and 7.5-8.5 years old children. In Experiment 3, the summation and preserved conditioned inhibition procedures were simultaneously applied to a group of 7.5-8.5 years old children.

EXPERIMENT 1

The experiment consisted of a task where each participant had to try out a “new computational game for children” patterned after Beckers, et al. (2005). In the game, aliens may or may not cause rain after shooting a cloud with their guns. The participants were trained with alternate trials, where aliens A and B always provoked 8 drops of rain each time they shot the cloud separately, and aliens C and D provoked no rain. Positive and negative compound trials formed by two aliens that shoot simultaneously the cloud were also included as control trials (EF and GH, respectively). They were then tested and asked to predict how many drops of rain will be provoked by the trained (A, B, C, D, EF and GH) and novel cues (AB and CD). The test allowed to examine if a compound is processed elementally (if the participants judge the amount of rain that falls given cue AB is greater than that to cues A and B separately) or configurally (if the participants judge the amount of rain to the cue AB is the same than to cues A and B individually).

It should be remarked that the use of a quantitative outcome during training (8 versus 0 drops of rain) and ratings of predicted intensity during testing was a choice based on our previous findings showing that these procedures effectively avoid ceiling effects in summation designs (Soto, Vogel, Castillo and Wagner, 2009).

METHOD

Participants. Twenty-six children were divided into two groups. The first group, called “5 year old group” consisted of 13 participants ranging from 54-66 months of age (Mean= 62.07; SD= 5.17). The second group, called “8 years old group” ranged from the ages of 93-108 months (Mean= 100.92; SD= 5.17). Neither group had previous experience in similar studies. The children’s participation was voluntary and authorized by one of his or her parents who previously signed an informed consent form. Each participant received a toy as a gift upon terminating the task.

Instruments. Experimental sessions were performed and registered in a laptop with a Sempron AMD of 1,60 GHz, 894MB RAM memory and an ATI Radeon Xpress 1100 video card, and a 15 inch video screen and programmed with e-prime version 1.1. The use of this software allowed a standardized automatic presentation of experimental stimuli, the recording of data and the evaluation of results. All participants were individually tested with the assistance of an evaluator.

Procedure. The experimental task was performed in an isolated chamber prepared *ad hoc* for the research. During each evaluation, only the participant and the evaluator were present. The task was completely performed by the participant who was seated in front of the laptop from which the experimental routine was presented. At the start the experimental session, the participant was informed that his or her mission was to try out a new computer game. The routine started by showing the written instructions on the screen accompanied by a recorded female voice reciting the instructions on the screen.

A pre-testing phase was then introduced. Its purpose was to determine if the participant had the basic knowledge to follow the instructions presented on the screen and to handle the keyboard. In this phase, all keys to be employed in the experimental routine were presented by themselves in a chance distribution, and the child was asked to press each key. The keys involved in each pre-test trial were A, B, C, D, E, S, N and the SPACE BAR. Each key was presented randomly 4 times, in 4 blocks of trials. Only those subjects who succeeded in understanding these preliminary instructions were included in the experiment.

The standard pre-test instruction was as follows (in Spanish):

PRESS KEY "S" TO CONTINUE

Once the preliminary phase was mastered the following instructions appeared on the screen:

In this new task you will be shown aliens shooting at a cloud. You have to learn WHICH of the aliens CAN and which CANNOT make rain.

Each time an alien appears shooting, you will have to tell whether or not it is going to rain by pressing a key on the computer. There will immediately appear a cloud with drops of rain or without drops of rain, showing what happened after the shooting. Pay attention to what happens after the shot, since you will be asked about which aliens MAKE RAIN and which aliens DO NOT MAKE RAIN.

PRESS THE SPACE BAR TO CONTINUE.

To make sure that the instructions on the screen were understood, the following instruction appeared:

So, your task consists of learning which aliens MAKE rain and which aliens DO NOT MAKE rain.

To indicate they make rain press key "S" and press key "N" to indicate they won't make rain.

You should press only ONE key

PRESS THE SPACE-BAR TO CONTINUE

In general terms, the experimental situation consisted of each subject playing a game in which had to learn which alien (experimental stimuli) made rain when they shot at a cloud with a laser pistol. The procedure consisted of two main phases. The training phase, in which participants were given trials where one or more aliens shoot to the cloud. The subjects were then consulted what would happen after the aliens shot the cloud. To answer, the participants had to select one of two alternatives indicated on the screen of the computer ("S" or "N"). Immediately after the response was given, the participant received feedback through the picture of a cloud that appeared with or without drops of water. During testing phase, aliens appeared separately and the participants were asked if it was going to rain or not. To respond, the participant had to choose between 5 images of clouds containing 0, 2, 4, 8 and 16 drops of rain respectively. The images were shown at the right hand corner of the screen, accompanying each alien shown in the center of the screen.

Table 1 depicts the conceptual design of the experiment where each letter represents a specific alien and the symbols "+"and "-" represent the presence and absence of rain, respectively. Training included trials in which aliens A and B were always followed by a cloud with 8 drops of water (A+ and B+) and aliens C and D were always followed by a cloud with no drops of water at all (C- and D-). A compound stimulus (i.e., two aliens shooting at the same time) was included that was followed by a cloud with 8 drops of water (EF+) and a second compound stimulus not followed by rain (GH-). Each participant received a total of 48 trials (8 of each type) presented randomly. The assignment of specific aliens to the conditions A-H was partially counterbalanced across the participants by means of their different allocations in one of five subgroups, each with a different assignment of aliens as A-H. The aliens were 5x 3 cm drawings appearing in the bottom of the computer screen that varied in a number of features such as presence versus absence of antennas, fat body versus thin body, round face versus oval face, etc.

Table 1. Experimental designs

	Training phase 1	Training phase 2	Test
Experiment 1	A+, B+, EF+, C-, D-, GH-		A, B, EF, AB, C, D, GH, CD
Experiment 2	A+, AB-, B-, DE+,	B+, C-	A, B, AB, C, DE
Experiment 3	A+, AB-, B-, DE+	B+, F+	A, B, C, F, AB DE, AF, BF

Note. Letters A-H represent different aliens that could be followed (+) or not followed (-) by the consequence (drops of water).

At the end of training, summation was examined by asking the participants to estimate how many drops of rain (0, 2, 4, 8 and 16) will follow the shootings of A, B, and the new compound AB (in addition to all the other filler cues). Given that the participants were asked to predict the amount of the outcome that will follow the presence of the cue, and not the degree to which the cue caused the outcome, the ratings should be taken as measures predictive learning.

RESULTS AND DISCUSSION

Following Beckers et al. (2005) the number of raindrops selected by each participant was scored from 1 (0 drops) to 5 (16 drops).

Figure 1 presents the mean predictive ratings for the individually trained cues A and B, for the trained compound (EF) and for the novel compound (AB) in the two groups of Experiment 1. As can be seen in the Figure, both groups showed summation in the form of greater predictive ratings to the novel AB than to the previously trained cues A, B and EF. The figure depicts also the predictive rating for the cues trained as negative (C, D, and GH) and for the novel "negative" compound (CD), which were very low, indicating that the children learned the discrimination.

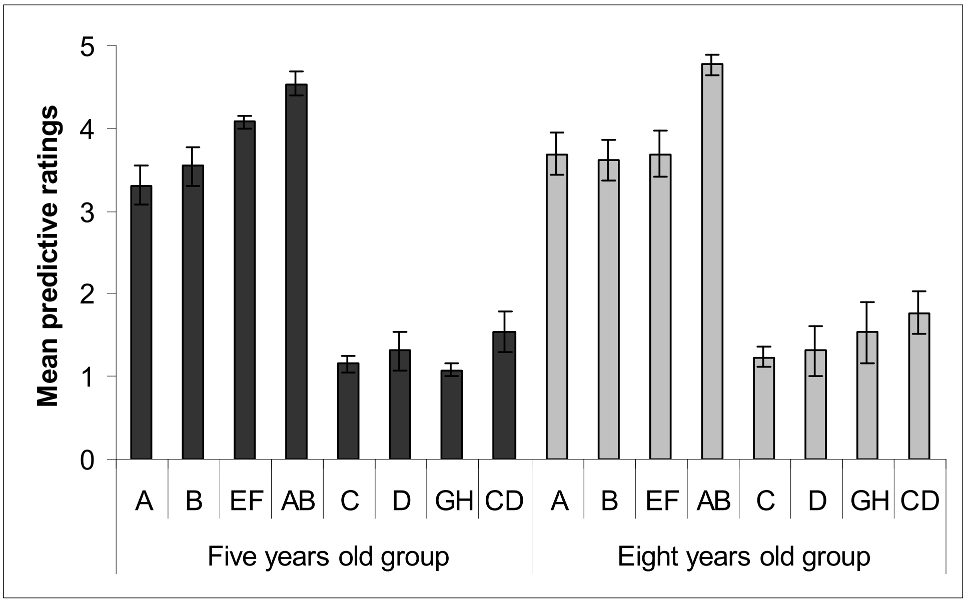

Figure 1: Mean predictive judgments assigned to each experimental cue during testing in Experiment 1. Error bars are standard errors of the means.

The reliability of these observations was confirmed by a 2 (group) X 8 (cue: A, B, AB, C, D, E, EF, GH) mixed design ANOVA, which indicated a reliable main effect of cue ($F(7, 168) = 74.119$; $p < 0.001$; partial $\eta^2 = 0.755$); but not reliable effect of group ($F(1, 24)= 2.310$; $p=0.142$; partial $\eta^2= 0.088$) nor group x cue interaction ($F(7, 168)= 0.646$; $p=0.718$; partial $\eta^2= 0.026$).

The summation effect was confirmed by Bonferroni post hoc comparisons, which indicated that the ratings assigned to cue AB were significantly higher than to A, B and EF ($ps < 0.007$) and that cues A, B and EF did not differ reliably from each other ($ps=1.000$). Likewise, predictive ratings to the negative cues (C, D, CD and GH) were significantly lower than the ratings to every positive cue ($ps <0.007$).

In conclusion, the participants of both age groups processed the cues as separate elements, supporting the elemental associative view of predictive learning as proposed by Rescorla Wagner (1972). This evidence of summation in predictive learning of Children replicates the findings of Collins and Shanks (2006) and Soto et al. (2009) in adults, suggesting that this pattern of behaviour is present early in the development.

EXPERIMENT 2

The results of Experiment 1 provided evidence of elemental processing when subjects are asked to evaluate a novel cue that has not been experienced previously (AB) and whose sole available information was the predictive value of its constituent elements (A and B). Experiment 2 intends to evaluate whether the subjects continue operating elementally in an experimental condition in which they receive information about AB that is subsequently contradicted by the information of the elements. To this end, the participants were evaluated with a typical preserved conditioned inhibition procedure (Pearce and Wilson, 1991). As can be seen in Table 1, this experiment consisted of two phases. During the first phase, cue A was followed by the consequence (A+) and cues B and AB were not followed by the consequence (B- and AB-). In the second phase, the predicted value of B was reversed, such that it was followed by the consequence (B+). In testing, the level of response to AB was compared to those of A and B. If the participants code the stimuli elementally, responding to AB should be based on the addition of the predictive values of A and B, and therefore, would be expected to be greater than responding to its elements. Alternatively, if the stimuli are processed as configurations, response to AB should be equal or less than that to its components, preserving what was acquired during the first phase.

METHOD

Participants. Twenty-six children were divided into two age groups as in the Experiment 1, with a total of 13 children in each group. The first group consisted of children between the ages of 56 to 67 months (Mean=66.21 months; SD=5.96) and group 2 was composed of children of ages between 92-106 months (Mean= 104.11; SD=6.87). The children had no previous experience with similar studies. The participation of the children followed the same criteria as in Experiment 1.

Instruments. The instruments were the same as those employed in Experiment 1.

Procedure. The same predictive learning procedure as in Experiment 1 was used, except for the contingencies described in Table 1. In phase 1, participants received regular conditioned inhibition training with A+B-AB-, followed by a "retroactive interference" procedure in phase 2 with B+. The aim is to compare the level of responses to AB vs A and B in test. As shown in Table 1, the participants also received filler trials with DE+ and C- in phases 1 and 2, respectively, with the purpose of creating a more complex task and to avoid that children apply general rules to the production of rain by compound versus elements.

RESULTS AND DISCUSSION

Figure 2 presents the mean predictive ratings obtained in the testing phase of Experiment 2, which indicate no evidence of summation in either group, since the ratings to AB were clearly lower than those to its components A and B.

These results were confirmed by a 2 (age: 5 years old and 8 years old) x 5 (cue: A, B, C, AB, and DE) mixed ANOVA, indicating a reliable main effect of cue (F (4, 96) =279.103; $p<0.001$; partial $\eta^2= 0.921$), but no reliable effects of age ($F(1, 24)=1.5$; $p=0.200$; partial $\eta^2=0.059$) nor cue x age interaction ($F(4, 96)=0.207$; $p=0.934$; partial $\eta^2=0.009$). Bonferroni post hoc comparisons indicated that the ratings assigned to AB were significantly lower than those assigned to its elements A and B ($ps<0.001$), confirming absence of summation and the preservation of what was learned in the first phase.

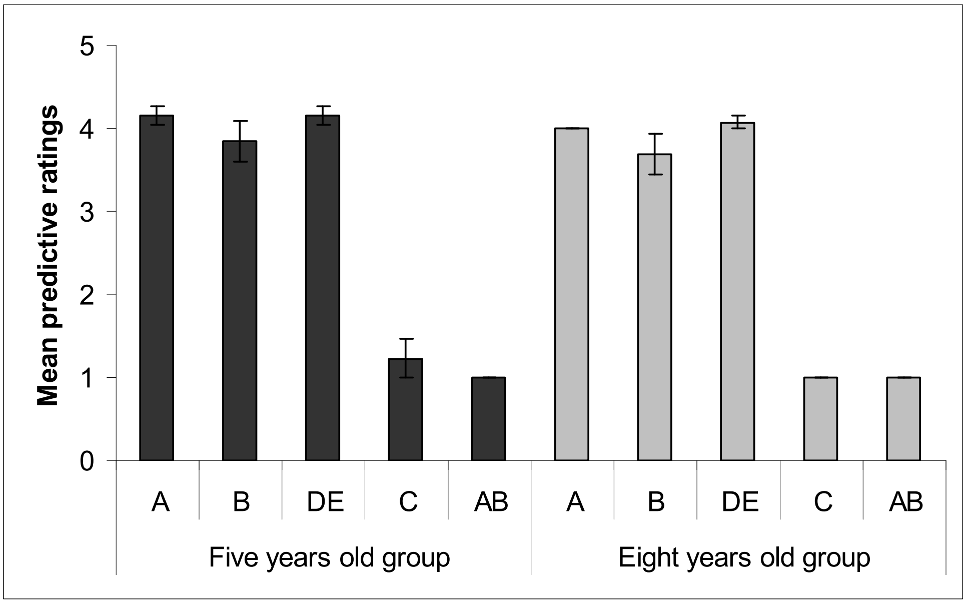

Figure 2. Mean predictive judgments assigned to each experimental cue during testing in Experiment 2. Error bars are standard errors of the means.

Additionally, the cues trained positively (A, B and DE) did not differ from each other ($p>0.518$) and received reliably greater predictive ratings than the "negative" cue (C $ps <0.001$), suggesting that participants learned to discriminate between stimuli predicting a consequence and those that do not.

These results support the configural view of associative learning and contradict, in principle, the results of Experiment 1. Additionally, they are in agreement with previous reports in predictive learning in adults (Williams, 1995) and Pavlovian conditioning in animals (Pearce and Wilson, 1991), supporting the generality of the preservation of conditioned inhibition phenomenon.

EXPERIMENT 3

The purpose of this experiment was to replicate the findings of experiments 1 and 2 in a single experiment. This was achieved by combining the summation and conditioned inhibition procedures as shown in Table 1. Simple summation was examined by comparing AF after training with A+ in the first phase and with F+ in the second phase; and preservation of conditioned inhibition was evaluated by comparing AB, after training with A+AB-B- in the first phase, and with B+ in the second phase. If the results of Experiment 1 are replicable with this procedure, AF should be greater than A and F, and BF should be greater than B and F (summation). Likewise, if the results of Experiment 2 are replicable with this procedure, then AB should be smaller than A and B (preservation of conditioned inhibition).

METHOD

Participants. As no difference by age was found in experiments 1 and 2, Experiment 3 was conducted with a single age group. The group consisted of 14 children between the ages of 73 to 103 months (Mean=90.86 months; SD=8.79) treated exactly as in experiments 1 and 2.

Instruments. The instruments were the same as those employed in experiments 1 and 2.

Procedure. The same predictive learning procedure as in experiments 1 and 2 was used, excepting for the contingencies described in Table 1. As can be seen, the design is exactly the same as in Experiment 2 with the addition of F+ in the second phase, which was used to examine simple summation.

RESULTS AND DISCUSSION

Figure 3 shows the mean predictive ratings for the cues involved in the simple summation test (A and F versus AF; B and F versus BF) and for the preservation of conditioned inhibition test (A and B versus AB). As can be seen, there was a clear evidence of simple summation since responding to the cues AF and BF was greater than that to its respective elements. Alternatively, there was also a clear evidence of preservation of conditioned inhibition since responding to AB was substantially lower than responding to A and B.

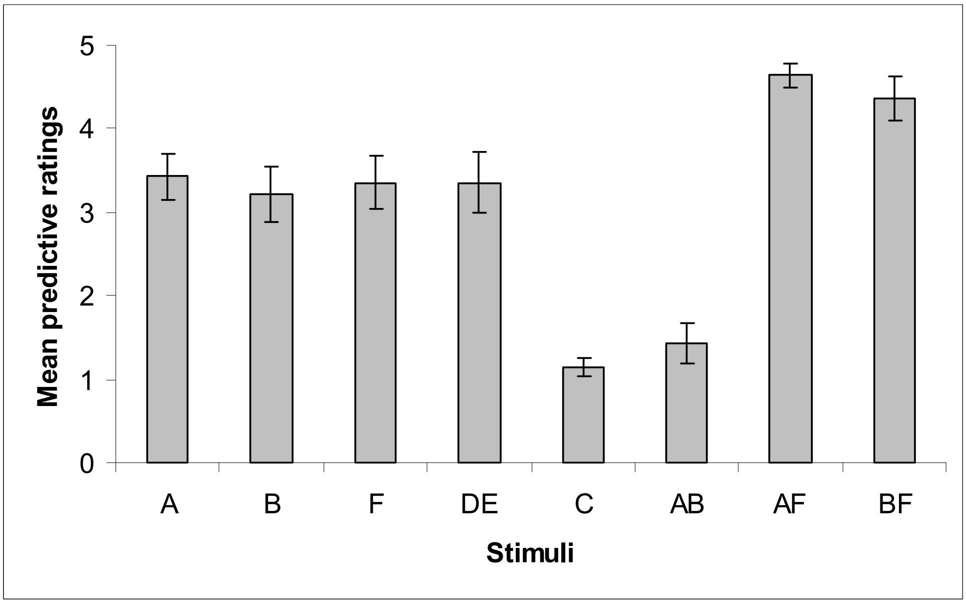

Figure 3. Mean predictive judgments assigned to each experimental cue during testing in Experiment 3. Error bars are standard errors of the means.

The reliability of these observations was evaluated by a repeated measures ANOVA with cue as factor. There was a reliable overall effect of cue ($F(7, 91) = 30.262$; $p<0.001$; partial $\eta^2=0.700$). Bonferroni post hoc comparisons confirmed, in general, the reliability of the simple summation effect since AF was reliably greater than A and F ($ps<0.006$); and BF was significantly greater than B ($p=0.003$) and marginally greater than F ($p=0.052$). Regarding that the post hoc comparisons were conducted with the very conservative Bonferroni procedure, the data can be taken as supportive of the summation effect, replicating the findings of Experiment 1.

On the other hand, the post hoc test indicated that the mean predictive ratings for AB was significantly lower those for its elements A and B ($ps<0.034$), confirming the preservation of conditioned inhibition and replicating the findings of Experiment 2.

GENERAL DISCUSSION

The results of experiments 1 and 2 provided evidence that children between 4 -9 years old use an elemental type of processing when asked to evaluate a novel compound which has not been presented previously (Experiment 1) and a configural-type of processing when asked to evaluate a compound that has been trained as a part of a conditioned inhibition procedure (Experiment 2). This is in agreement with separated reports of summation (Collins and Shanks, 2006; Soto et al., 2009) and preservation of conditioned inhibitions in adults (Williams, 1995). The outcome of Experiment 3 is the first demonstration of the two effects in a single experiment. Furthermore, none of the experiments provided evidence on the potential influence of developmental variables on the codification strategies in this type of tasks.

From a theoretical point o view, these results pose a problem for several theories of associative learning. On the one hand, purely elemental theories like that of Rescorla and Wagner (1972), predict the summation of responding obtained in experiments 1 and 3 but not the preservation of conditioned inhibition seen in experiments 2 and 3. On the other hand, purely configural theories like that of Pearce (1994), predict the preservation of conditioned inhibition but not summation.

It is important to notice, however, that the dilemma posed for the contrasting results of simple summation and preserved conditioned inhibition experiments, can be solved, in principle within both configural and elemental approaches. One example is one elemental model proposed by Allan Wagner (2003). This theory, named *Replaced Element Model* (REM), suggests that changing the context in which a particular stimulus is presented leads to changes in its representation. Specifically, it proposes that any stimulus is represented by a set of elements, some of which are context dependent and some others are not. Context independent elements are activated whenever the stimulus is presented, regardless of what other stimuli are present, while context dependent elements do depend on the presence or absence of other stimuli. For example, if stimulus A alone is represented by "a_i" and "$a_{\sim b}$" and B alone is represented by "b_i" and "$b_{\sim a}$", the compound AB is assumed to be represented by "a_i", "a_b", "b_i", and "b_a". In this example, a_i and b_i are context independent elements and "a_b" and "b_i" are context dependent element that are replaced by "$a_{\sim b}$" and "$b_{\sim a}$" , respectively depending on the CS components (i.e., AB versus A alone and B alone).

The fact that, according to REM, some elements of A and B alone are also activated in the compound AB (i.e., a_i and b_i) is consistent with the elemental model of Rescorla and Wagner (1972). Likewise, the addition of new configural elements in the compound AB (a_b and b_a) is consistent with the unique cue hypothesis proposed by Whitlow and Wagner (1972), and the inactivation or "replacement" of context dependent elements "$a_{\sim b}$" and "$b_{\sim a}$" is consistent with the configural model proposed by Pearce (1994).

Thus, different degrees of summation or preservation of conditioned inhibition can be obtained by varying the relative proportion of context dependent and context independent elements, which is given by a parameter, r ($0 \leq r \leq 1$) For instance, if context dependent elements are assumed to be of little importance (low r), the effect of replacement will be negligible in REM, and a compound cue will be very similar to the sum of its elements, as predicted by the Rescorla Wagner model. Conversely, if context dependent elements are assumed to be of sizeable importance (high r), the effect of the replacement will be considerable and a compound will differ from the sum of its elements, as predicted by Pearce's (1994) model. Figure 4 shows the results obtained with a simulation performed with an intermediate level of replacement (r=0.3), which was found to produce the best fit for the results of experiments 1, 2 and 3 of the present research (for more details on REM simulations, see Vogel et al. , 2007 or Wagner, 2003).

Similarly, Pearce (1994) proposed that his configural model can account for summation if it is assumed that the context is part of the stimulation complex. Thus, by assuming that the context is equivalent to cue X, the summation experiment becomes an AX+ BX+ training with ABX as the novel compound to be tested. Wagner and Vogel (2008) presented simulations of summation and conditioned inhibition based on Pearce's model assuming different saliences for the contextual cues and found that summation can be obtained with a relatively salient context and that preserved conditioned inhibition can be obtained with comparatively less salient context. It is not clear whether there is an intermediate value, as is the case of REM, in which both results would be accounted simultaneously.

An important conclusion which should be extracted from this study is that the distinction between pure elemental and pure configural processing as held traditionally, has not major theoretical relevance at present. Any current theory of associative learning has to recognize elemental as well as configural processes. By this assumption, REM, for instance, can account for the full set of data of this research without appealing to parametric variability. However, it is very unlikely that a single parametric value could account for the full set of data available in the literature. Indeed, there are examples and contra-examples of both, summation and preservation of conditioned inhibition. The challenge for researchers within the associative perspective is to find out how and why the weight assigned to configural (or context dependent elements) varies in different circumstances, so that current theories, like REM or Pearce's modified model can be improved and tested.

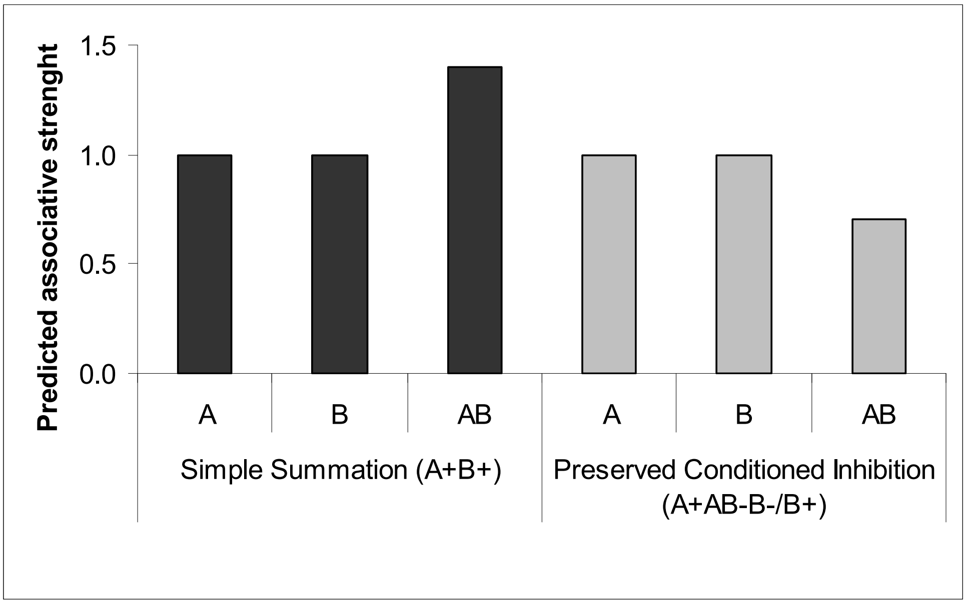

Figure 4. Predicted asymptotic associative strengths for experiments 1 and 2. The plot presents simulations conducted with the REM model (Wagner, 2003) with a level of replacement r=0.3.

Finally, it is important to recognize that investigations testing the contrasting predictions of configural and elemental theories of associative learning have been traditionally conducted with Pavlovian conditioning procedures and non human participants. The assumption that there is an isomorphism between Pavlovian conditioning and the learning of cue-outcome relationships has several potential complexities that deserve some consideration in future research. For instance, there is considerable debate as to whether this isomorphism should be accepted without qualification or some influence of higher order processing should also be recognized (e.g., Cheng, 1997). Indeed, several authors have proposed that ratings about cue-outcome relationships may depend not only on the cue-outcome association, but also on the type of statistical computation elicited by the question used to obtain the ratings (Vadillo and Matute; 2007). Consistent with this notion, there is some evidence that testing with questions that encourage causal judgments disposes participants to use cue-outcome contingency indexes, whereas testing with questions that encourage predictive judgments disposes participants to use indexes based on the probability of the outcome given the cue (e.g., Cobos, Caño, López, Luque & Almaraz, 2000; Vadillo & Matute, 2007; Vadillo, Miller, & Matute, 2005). In the face of these empirical differences between predictive and causal learning, future studies should explore the generality of the present results using a broader spectrum of testing strategies.

RESUMEN

Sumación en el aprendizaje predictivo en niños. Una cantidad considerable de investigación ha examinado las predicciones contrarias de los modelos elementalistas y configuracionales del aprendizaje. Uno de los métodos más simples para distinguir entre estos dos enfoques es la prueba de sumación, en la cual se examina la fuerza asociativa de un estímulo compuesto novedoso (AB) después del entrenamiento por separado de cada uno de sus elementos (A+ y B+). El enfoque configuracional predice que la fuerza asociativa del compuesto será aproximadamente el promedio de la fuerza asociativa de sus componentes, mientras que el enfoque elementalista predice que la fuerza del compuesto será mayor que la de cada uno de los elementos por separado. La prueba de sumación ha arrojado evidencia contradictoria en experimentos con animales así como también con humanos adultos. El propósito de la presente investigación fue examinar el fenómeno de sumatoria en el aprendizaje predictivo en niños de 5-9 años de edad. Los resultados arrojaron evidencia de sumatoria (AB mayor que A y B) luego un procedimiento de entrenamiento con "sumatoria simple" (A+ B+ y test con AB; Experimento 1, n=26), pero no evidencia de sumatoria luego de un procedimiento de "preservación de la inhibición condicionada" (A+B-AB- seguido por B+ y test con AB; Experimento 2; n=26). En el Experimento 3 ambos efectos se observaron simultáneamente (n=14). Estos resultados son consistentes con hallazgos en condicionamiento clásico con animales y aprendizaje predictivo con adultos. Se discuten algunas alternativas teóricas dentro de los enfoques elementalista y configuracional.

REFERENCES

Aslin, R. N. & Smith, L. B. (1988). Perceptual development. *Annual Review of Psychology*, *39*, 435-473

Aydin, A. & Pearce, J.M. (1995). Summation in autoshaping with short and long-duration stimuli. *Quarterly Journal of Experimental Psychology*, *48B*, 215-234.

Beckers, T., Van den Broeck, U., Renne, M., Vandorpe, S., De Houwer, J. & Eelen, P. (2005). Blocking is sensitive to causal structure in 4-year-old and 8-year-old children. *Experimental Psychology, 52*, 264-271.

Brandon, S.E., Vogel, E.H. & Wagner, A.R. (2000). A componential view of configural cues in generalization and discrimination in Pavlovian conditioning. *Behavioral Brain Research*, *110*, 67-72.

Burns, B. (1986). Relationship of perceived stimulus structure and intelligence: Further tests of a separability hypothesis. *American Journal of Mental Deficiency, 91*, 196-200.

Cheng, P. W. (1997). From covariation to causation: A causal power theory. *Psychological Review*, *104*, 367 -405.

Cobos, P.L., Caño, A., López, F.J, Luque J.L., & Almaraz J. (2000). Does the type of judgment required modulate cue competition? *Quarterly Journal of Experimental Psychology*, *53B*, 193-207.

Collins, D. J., & Shanks, D. R. (2006). Summation in causal learning: Elemental processing or configural generalization? *Quarterly Journal of Experimental Psychology, 59*, 1524-1534.

Gardner, W.R., (1974). *The processing of information and structure*. Potomac, MD: Erlbaum.

Kundey, S. and Wagner, A.R. (2004). *Further tests of elemental versus configural models of Pavlovian conditioning.* Paper presented at the meetings of the Comparative Cognition Society, Melbourne Florida, March, 2004.

Lachnit, H. (1988). Convergent Validation of Information Processing Constructs With Pavlovian Methodology. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 1 143-152

Melchers, K.G., Shanks, D.R. & Lachnit, H. (2008). Stimulus coding in human associative learning: Flexible representations of parts and wholes. *Behavioural Processes, 77*, 413-427.

Myers, K.M., Vogel, E.H., Shin, J. & Wagner, A.R. (2001). A comparison of the Rescorla-Wagner and Pearce models in a negative patterning and a summation problem. *Animal Learning and Behavior, 29*, 36-45.

Pearce, J.M. (1994). Similarity and discrimination: A selective review and a connectionist model. *Psychological Review*, *101*, 587-607.

Pearce, J.M. (2002). Evaluation and development of a connectionist theory of configural learning. *Animal Learning and Behavior*, *30*, 73-95.

Pearce, J. M. & Wilson, P. N. (1991). Failure of excitatory conditioning to extinguish the influence of a conditioned inhibitor. *Journal of Experimental Psychology: Animal Behavior Processes*, *17*, 519-529.

Rescorla, R.A. (1997). Summation: Assessment of a configural theory. *Animal Learning and Behavior*, *25*, 200-209.

Rescorla, R.A. & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. En A.H. Black & W.F. Prokasky (Eds.). *Classical Conditioning II: Current Theory and Research*, (pp. 64-99). New York: Appleton-Century-Crofts.

Smith, L. B. & Kemler, D. G. (1977). Developmental trends in free classification: Evidence for a new conceptualization of perceptual development. *Journal of Experimental Child Psychology*, *24*, 279-298.

Soto, F., Vogel, E., Castillo, R., & Wagner, A. (2009) Generality of the summation effect in human causal learning. *Quarterly Journal of Experimental Psychology*, *62*, 877-889.

Vadillo, M. A., & Matute, H. (2007). Predictions and causal estimations are not supported by the same associative structure. *Quarterly Journal of Experimental Psychology*, *60*, 433-447.

Vadillo, M. A. Miller, R. R, & Matute, H. (2005). Causal and predictive –value judgments, but not predictions, are based on cue-outcome contingency. *Learning & Behavior*, *33*, 172-183.

van Osselaer, S. M. J., Janiszewski, C., & Cunha, M. (2004). Stimulus generalization in two associative learning processes. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *30*, 626-638.

Vogel, E.H., Díaz, C., Ramírez, J., Jarur, M.C., Pérez-Acosta, A. & Wagner, A.R. (2007). Desarrollo de un programa computacional para simular las predicciones del modelo de elementos reemplazados (REM) de condicionamiento pavloviano. *Psicothema, 19*, 506-514.

Wagner, A.R. (2003). Context-sensitive elemental theory. *Quarterly Journal of Experimental Psychology*, *56B*, 7-29

Wagner, A. R. & Vogel, E. H. (2008). Configural and elemental processing in associative Learning. *Behavioural Processes, 77*, 446-450.

Whitlow J.W. & Wagner, A.R. (1972). Negative patterning in classical conditioning: Summation of response tendencies to isolable and configural components. *Psychonomic Science, 27*, 299-301.

Williams, D.A. (1995). Forms of inhibition in animal and human learning. *Journal of Experimental Psychology: Animal Behavior Processes, 21*, 129-142.

Williams, D. A. & Braker, D. S. (1999). Influence of past experience on the coding of compound stimuli. *Journal of Experimental Psychology: Animal Behavior Processes, 25*, 461-474.

(Manuscript received: 13 March 2009; accepted: 16 June 2009)