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THE EMERGENCE OF COGNITIVE SHORT-TERM PLANNING: PERFORMANCE OF PRESCHOOLERS IN A PROBLEM-SOLVING TASK

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Abstract

The aim of this study is to identify patterns of the cognitive planning process of young children emerging in the context of a problem solving task. Using a complex dynamic systems approach, this paper depicts the main features of cognitive planning in the short term. Participants were 45 preschool children (aged 3.5 and 3.6 years) of which two case studies are described in detail. The microgenetic method was used to capture, in two months, the planning process in real time during six sessions of data collection. Thus, 96 measuring points were obtained for each child of the sample. The instrument used was a problem solving task in a virtual format, which requires the development of a plan to attain the goal. The first part of the analysis characterizes the children's planning performance by means of cluster analysis. Two clusters were identified as a result of this analysis. In order to illustrate the performance of the sample, one child from each cluster was randomly selected as a case study. The second part of the analysis describes the two case studies. The State Space Grids (SSG) technique was used to show the short-term emergence of cognitive planning. Results of the case studies revealed two types of performance: a *reduction pattern* and a *stable pattern* of cognitive planning. These patterns indicate the ability of children to integrate the constraints of the task and consider future states in their actions. In contrast to the literature, the findings of this study reveal the resources in planning skills of preschoolers, such as self-regulation of actions aimed at attaining a goal and anticipation of future states.
Key words: cognitive development, computer game, cognitive planning, preschoolers, state space grid technique, variability.

LA EMERGENCIA DE LA PLANIFICACIÓN COGNITIVA A CORTO PLAZO: DESEMPEÑO DE NIÑOS PREESCOLARES EN UNA TAREA DE RESOLUCIÓN DE PROBLEMAS

Resumen

El objetivo del presente estudio es identificar los patrones del proceso de planificación cognitiva de niños pequeños que tienen lugar en el contexto de una situación de resolución de problemas. Utilizando un enfoque de sistemas dinámicos complejos, el presente estudio describe las principales características de la planificación cognitiva a corto plazo. Los participantes fueron 45 niños en edad preescolar (3,5 y 3,6 años), de los cuales se describen en detalle dos estudios de caso. El método microgenético fue utilizado para capturar, en dos meses, el proceso de planificación en tiempo real durante seis sesiones de recogida de datos. De esta manera se obtuvieron 96 puntos de medición por cada niño de la muestra. Como instrumento se utilizó una tarea de resolución de problemas en un formato virtual, que exige la elaboración de un plan para alcanzar la meta. La primera parte del análisis consistió en caracterizar los desempeños de planificación de la muestra mediante el análisis de conglomerados. Como resultado, dos *clústers* fueron identificados. Posteriormente, para ilustrar los desempeños de la muestra, se seleccionó al azar un niño de cada *clúster* como estudio de caso. La segunda parte del análisis consistió en describir los dos estudios de caso. Se utilizó la técnica *State Space Grids* (SSG) para mostrar el surgimiento a corto plazo de la planificación cognitiva. Los resultados de los estudios de caso revelaron dos tipos de desempeño: un *patrón de reducción* y un *patrón estable de planificación cognitiva*. Estos patrones en los desempeños indican la capacidad de los niños para integrar las restricciones de la tarea y considerar estados futuros en sus acciones. En contraste con la literatura, los resultados de este estudio revelan los

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recursos de habilidades de planificación en niños preescolares, tales como su auto-regulación de acciones dirigidas a una meta y la anticipación de futuros estados.
Palabras clave: desarrollo cognitivo, juego de computador, planificación cognitiva, preescolares, técnica *state space grid*, variabilidad.

A EMERGÊNCIA DO PLANEJAMENTO COGNITIVO A CURTO PRAZO: DESEMPENHO DE CRIANÇAS PRÉ-ESCOLARES EM UMA TAREFA DE RESOLUÇÃO DE PROBLEMAS

Resumo

O objetivo deste estudo é identificar os padrões do processo de planejamento cognitivo de crianças pequenas, que acontecem no contexto de uma situação de resolução de problemas. Utilizando um enfoque de sistemas dinâmicos complexos, o presente estudo descreve as principais características do planejamento cognitivo a curto prazo. Os participantes foram 45 crianças em idade pré-escolar (3,5 e 3,6 anos), dos quais se descrevem em detalhe dois estudos de caso. O método micro genético foi utilizado para capturar, em dois meses, o processo de planejamento em tempo real durante seis sessões de coleta de dados. Desta maneira obtiveram-se 96 pontos de medição por cada criança da mostra. Como instrumento utilizou-se uma tarefa de resolução de problemas em um formato virtual, que exige a elaboração de um plano para alcançar a meta. A primeira parte da análise consistiu em caracterizar os desempenhos de planejamento da mostra mediante a análise de conglomerados. Como resultado, dois *clústers* foram identificados. Posteriormente, para ilustrar os desempenhos da mostra, selecionou-se aleatoriamente uma criança de cada *clúster* como estudo de caso. A segunda parte da análise consistiu em descrever os dois estudos de caso. Utilizou-se a técnica *State Space Grids* (SSG) para mostrar o surgimento a curto prazo do planejamento cognitivo. Os resultados dos estudos de caso revelaram dois tipos de desempenho: um *padrão de redução* e um *padrão estável de planejamento cognitivo*. Estes padrões nos desempenhos indicam a capacidade das crianças para integrar as restrições da tarefa e considerar estados futuros em suas ações. Em contraste com a literatura, os resultados deste estudo revelam os recursos de habilidades de planejamento em crianças pré-escolares, tais como sua autorregulação de ações dirigidas a uma meta e a antecipação de futuros estados.
Palavras chave: desenvolvimento cognitivo, videogame, planejamento cognitivo, pré-escolares, técnica *state space grid*, variabilidade.

Cognitive planning, inference and hypothesis testing are some of the scientific skills present in young children (Puche-Navarro, 2000; Kuhn & Dean, 2004; Zimmerman, 2007). Scientific reasoning has been studied by examining how the empirical data is used in problem-solving and how it influences the elaboration of hypotheses (Klarh, 2005; Kuhn, 1989, 2007). In particular, cognitive planning can be studied by considering which information (empirical evidence) is used in the arrangement of a sequence of actions to reach a goal. In the planning process, the estimation of future states is crucial to understand the consequences of the selection of an initial action (plan) directed towards the goal. However, little is known about how cognitive planning- as a process- takes place and changes over time.

A framework that has enable psychologists to study how developmental processes emerge over time is the dynamic systems theory or complex systems approach (see Thelen & Smith, 1994; van Geert 2003, and Fischer & Bidell, 2006). From this approach, development is seen as a self-organized system evolving from the interaction of its components (Kunnen & van Geert, 2011). Therefore, the relevance of the complex system to the study of human behaviors is the focus on its temporary development in the observation of the variations or changes that occur in behaviors in a short- and long-term scale. As a result, variability (i.e. individual variability) is seen as a main property of behavior (van Dijk & van Geert, 2015). For decades, the study of development at the micro level has evidenced the variability between children solving the same task, but also the intra-individual variability of each child solving the same task (Siegler, 2002, Siegler, 2006; Miller & Coyle 1999; Adolph, Robinson, Young & Gil-Álvarez, 2008). From a complex systems approach, the variability is understood as a property of change (Yan & Fischer, 2002) and a main source of information because it works as an indicator of change (Granot, Fischer & Parziale, 2002; van Dijk & van Geert, 2002). Taking these aspects into account, the aims of the present study lie in exploring the emergence of cognitive planning in a short-time scale by identifying patterns of variability, and to contribute to a better understanding of the process of reasoning – as cognitive planning–in young children. A description of the core concepts of this study, such as cognitive planning and complex dynamics systems approach is presented below.

Cognitive planning has been studied with diverse populations, such as children, adolescents, adults and patients with cognitive impairment as a consequence of prefrontal lesions (Rattermann, Spector, Grafman, Levin, & Harward, 2001). Also, there are diverse tasks that have been used to demonstrate the use of planning such as virtual situations in which displacement is required through maps or three-dimensional space (Morganti, Carassa, & Geminiani, 2007); the building of towers called Tower of Hanoi and Tower of London (e.g., Bishop, et al., 2001) and naturalistic situations at school (e.g. Baker-Sennett, Matusov, & Rogoff, 2008). Despite the variety of participants and situations to study planning, the general trend of the methodological procedures is characterized by two main aspects: (a) Protocols and analysis based on the assessment approach of presence/absence of the skill. This perspective derives from neuropsychological studies (e.g. Bull, Espey, & Senn, 2004; Cazzato, Basso, Cutini, & Bisiacchi, 2010; Newman, Greco & Lee, 2009; Phillips, Wynn, McPherson & Gilhooly, 2001). In these studies, cognitive planning is examined as a crucial element of executive functions. In consequence, aspects such as the number of correct and incorrect plans and the reaction times -resulting from single measures- , are the focus of the planning analysis. (b) Comparison between age groups. These studies examine the level of complexity of the plans according to age. As a result, cognitive planning in children tends to be characterized by what they have to achieve in order to display an adult performance. Generally, these two methodological procedures are focused on punctual outcomes of the planning process. In contrast, the interest of the present study is to identify how the trajectories of preschool children develop in the short-term.

Most of the literature about cognitive planning in young children uses problem solving tests that require motor control. For instance, grasping tasks in two-year old children (Cox & Smitsman, 2006), and especially the use of the Tower of Hanoi and the Tower of London in children three to four years of age and older (e.g. Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008). Some of the findings on cognitive planning suggest that young children relate the mean to the goal. According to Cox y Smitsman (2006), the phases of grasping an object and the respective adjustment of the motor behavior indicate the manner in which children are able to integrate factors such as motor preferences and laterality. For these authors, the specific selection of the hands at different stages of the task, require adjustments or adaptations based on achievement of the goal. In addition, Claxton, McCarthy and Keen (2009) reveal that 18 and 19 months old children are able to plan an efficient sequence of actions when these actions are self-directed (e.g. spoon-mouth). However, it does not happen when the actions are not self-directed (e.g. using a hammer). The reason is that children are able to assess the immediate feedback of their behaviors when they constitute the target of their own actions. The study by Chen and Keen (2010) showed similar results with 18 and 24 months old children. Young children were able to plan a total sequence of movements to build towers with blocks, from the moment they grasped the blocks until they released them .The children integrated the information about the shape and size of the blocks with the height of the tower they were building. In this regard, the authors suggest that "the ability to link perceptual information with the proper motor actions suggests that an over-arching goal governed the entire sequence" (p. 1855).In summary, these studies revealed that young children are able to arrange a sequence of actions, adjusting their movements to achieve a goal by conceiving future states of the task.

Cognitive planning in preschoolers has been broadly studied in four- year old children with a problem solving test called "Tower of Hanoi" and their respective derivation task such as London Tower and Mexico Pyramid (Baughman & Cooper, 2007; Berg, Byrd, McNamara & Case, 2010; Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008; Matute, Chamorro, Inozemtseva, Barrios, Rosselli & Ardila, 2008). These studies are focused on age performance showing that the development of cognitive planning consolidates with time. For instance, four- year old children use long sequences of actions, while five-year old children use the search-ahead strategies to anticipate future states (Kaller, Rahm, Spreer, Mader & Unterrainer, 2008). In addition, reaction times show a decrease according with the increase of age. Some authors consider that the development of cognitive planning relates to the inhibitory functions (e.g. avoiding the obstacles of the tasks; reducing the number of actions to get the goal). Therefore, the older the child, the more structured and organized his skills are to select sequences to the goal by inhibiting non efficient answers. From the computational models, Baughman and Cooper (2007) suggested that young children of three and four years of age break the rules of the task because they have difficulties to inhibit the use of simple strategies. In contrast, these authors indicate that older children of five and six years of age are able to use successful strategies by inhibiting actions as a result of maturation of their executive functions.

These studies about feeding and grasping tasks showed that the sequence of actions and the relation of future states with the immediate actions are crucial for planning skills. The evolution of the onset of cognitive planning is built under two basic conquests: the elaboration of an ordered sequence and the anticipation of future states of the task. In other words, the core of planning is to discover what to do now in relation to a future time. According to these studies, these skills appear in younger children around two years of age. More specifically, previous research has found that future-oriented behavior emerged between the age of three and five (Hudson, Mayhew, & Prabhakar, 2011). At this period of development, children are able to relate past events to future events in their verbal reports, making decisions to pursue future goals. About future thinking, Atance (2008) reported that between three to five years of age children are able to elaborate plans that evidence behaviors related to future events, such as planning what things to take for a trip in a particular context (Hudson, Shapiro & Sosa, 1995, cited by Atance, 2008, p. 297). In addition, Atance and Meltzoff (2005) indicate that although children were able to plan the selection of functional objects related to the destination of the trip, they presented more difficulty when asked to explain their choices. Prabhakar and Hudson (2014) examined the ability of children aged three and four to use future-oriented behavior by using a three-dimensional model of a neighborhood where the children should make choices about the trajectories to go from a target house to a target store. The task included distracted elements as part of their demand. The authors found that four-year old children were able to plan two ordered and embedded future goals, while the three-year old ones were able to do it when a simplified demand of the task was presented, in other words, when the goals were non-contingent.

The findings about planning skills show that their development increases with age. For instance, the performance of children from three to six years of age is characterized by actions less elaborate, while children aged between seven and eight display more demanding performances. The poverty of the initial performance is explained by maturation and representational aspects of the task (Matute, et, al. 2008; Baughman & Cooper 2007). In other words, the low efficiency of young children is related to their understanding of isolated elements of the task.

In summary, the main characteristic of the reviewed studies is the adoption of the cross-sectional approach, comparing performances between ages and focusing on the consolidation of planning skills in older children. In addition, the main findings about the lack of control of actions in young children suggest that they have little regulation to execute a plan. This is evidenced in the use of immediate solutions, lack of anticipation of actions and omission –or breaking of rules –(Matute, et al. 2008; McCormack & Atance, 2011). However, the same studies indicated that these limitations disappear in the older ages (seven to eight years). In summary, the reviewed studies indicate that cognitive planning skills of three- year old children are characterized by the following restrictions: (1) focusing on partial aspects of the task, (2) difficulty for self-regulating actions (i.e. anticipating and systematizing sequences of actions), (3) breaking rules, and (4) limited flexibility to think about future states.

In order to explore the emergence of cognitive planning skills of young children in the short-term scale, this study examines the changes of the plans used by children to solve a problem task. A complex dynamic systems approach provides elements to study psychological processes in real-time. There is an agreement among researchers that developmental processes imply changes at different time-scales. For instance, the short-term scale can refer to a learning process happening in minutes or hours, and a long-term one refers to extended periods that can go from months to years. Evidence has shown that the "developmental processes are highly nonlinear, heterogeneous, and dependent on a wide range of factors" (Rose & Fischer, 2009, p. 417). Other characteristics of the developmental processes are the multi-causality as a relationship between diverse factors, and the discontinuity, or abrupt changes in behavior (Kagan, 2008, Spencer & Perone, 2008; Puche-Navarro, Combariza, Ossa, 2012). These characteristics of developmental processes required to leave behind the notion of "stages" as fixed upward sequences. Change processes at the macro and micro levels are then understood from the variability and discontinuity paths present in the trajectories of the subjects. In other words, the development in a short- and long-term is conceived as a non-linear process. Studies in several topics have shown evidence of nonlinearity, for instance, in language (e.g. van Dijk & van Geert, 2007), interaction behaviors (e.g. Hollenstein, Granic, Stoolmiller, & Snyder, 2004) and scientific reasoning (e.g. Meindertsma, Steenbeek & van Geert, 2013; Guevara, van Dijk & van Geert, 2014).The present study assumes a complex dynamic systems approach because it provides conceptual and methodological tools to study the qualitative changes that occur in cognitive development (Colunga & Smith, 2008; Combariza & Puche-Navarro, 2009; Guevara & Puche-Navarro, 2009; Spencer & Perone, 2008; van Dijk, & van Geert, 2002, 2007). In this case, developmental change corresponds to the study of cognitive planning. From the viewpoint of the complex dynamic systems, the patterns of variability give information about the dynamic nature of the change processes emerging in the intra-individual trajectories (Kelso, 2000; Rose & Fischer, 2009; van Dijk & van Geert, 2011, 2015). Therefore, the complex dynamic systems provide a framework to study cognitive planning as a process that takes place in real-time, and that can vary between the different attempts of the children to solve the task.

Based on the previous conceptual considerations, the present study is focused on understanding the dynamics of cognitive planning skills in preschool children. The authors have chosen to work with young children because they are in a period of emergence of planning skills, which become more consistent around the age of four to five years. The present study examines the dynamics of the short-term development of cognitive planning in preschoolers. The research questions addressed by this study are:

How does cognitive planning of preschoolers take place in the short-term during a solving-problem task?

Which are the main intra-individual patterns of cognitive planning used by preschoolers during a solving problem task?

METHOD

Design

Because from a complex dynamic systems approach studying processes requires observing changes over time, this study adopted a microgenetic method (Siegler & Crowley, 1991) to capture the real-time planning process. This method consists of repeated measures collected in a short-term scale. Thus, in this study data were collected of eight sessions throughout a period of two months, and taking an eight days period as an interval between sessions. In each session, 12 measurements per child were obtained, for a total of 96 measurements in the eight follow-up sessions.

Participants

Two case studies were selected from a convenience sampling of 45 preschoolers aged 3.5 and 3.6. All children were attending private childcare centers in two Colombian cities, belonging to a middle socio-economic level. A criterion taken into account was that all the childcare units should have provided the children with some computer based activities. Thus, children were familiar with this technology before taking part in the study. In addition, children's participation was based on the informed consent of their parents and the regulations of the ethical committee of psychology. The two case studies (i.e. Felipe and Alejandro) were randomly selected to illustrate two characteristic performances of the sample

Instrument

A solving problem task was designed in a virtual format of a computer game. The task demands the children to establish an ordered sequence of correspondence relations (see Figure 1). For example, the relationship between characters-object (e.g. cook-pot; monkey-banana) or between objects (e.g. mask & snorkel- paddle- fins; plant- watering can). The software of the game stored the total score of correct correspondences performed by the child (score from 1 to 4).

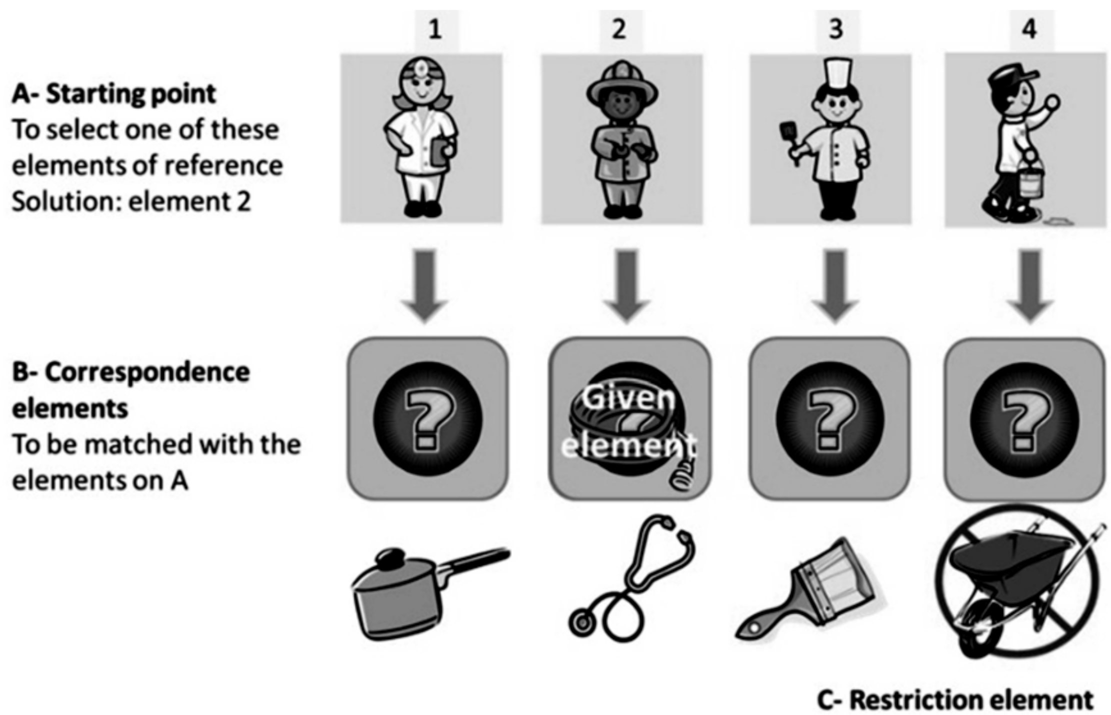


Figure 1. Example of the screen elements of the game

The game-task included four scenarios (see Figure 2): thematic, daily activities, entertainment and animals. In order to avoid memory bias, the scenarios were made with the same structure of correspondence between elements but using a different appearance. At the same time, each scenario included four related game screens. For instance, the entertainment scenario presented the following screens: a. sports, b. circus, c. ludo games d. party.

sequence in which they were introduced to the children. The procedure of the game consisted of a laptop with the game. The keyboard was covered leaving available only the two keys to operate the game: the 'Tab' key, to move over the elements on the screen, and the 'Enter' key, to select an element on the screen. The game was presented in two phases: a familiarization phase and a experimental phase. In the first phase, the researcher introduced a

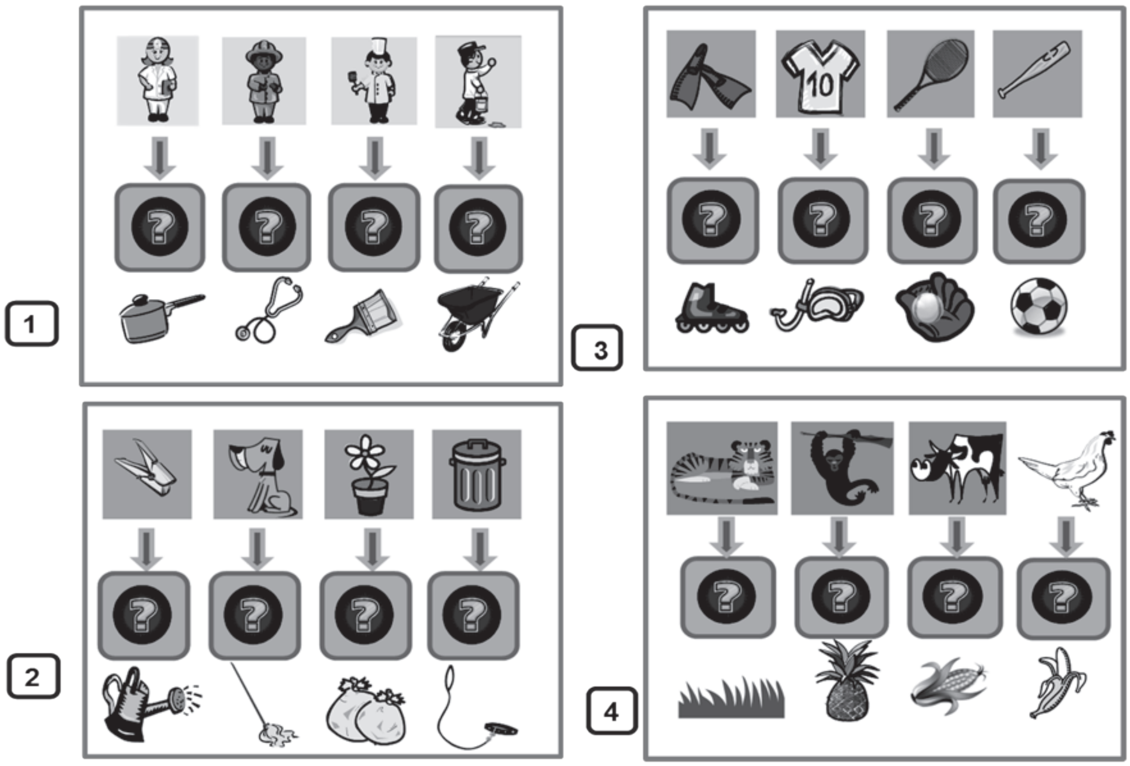


Figure 2. Game scenarios: 1. Thematic, 2. Daily activities, 3. Entertainment, and 4. animals.

The game demanded the use of cognitive planning as follows: (1) to plan the correspondence between the elements based on the previous knowledge, (2) to anticipate the future status of the actions to reach the goal and (3) to establish an organized sequence of steps (sub-goals) to reach the goal. The children not only needed to identify the correspondence between elements, but also the sequence in which the elements ought to be matched.

Procedure

Each task was presented individually to the children. The four scenarios of the game were randomly presented along the first half of the sessions and were presented again in the second half of the sessions keeping the initial

familiarization screen, explaining to the child the use of the two keys required to operate the game. Once the child responded correctly to the commands: *"please select X element on the screen" (using the Tab key)*, and *"now pick X element" (using the Enter key)*, the researcher started the second phase of the game. This phase consisted of presenting four experimental screens of the game (see Figure 2) which demanded the elaboration of a plan to attain the goal in a sequence of steps. For each screen, the child was allowed to make three attempts. In this phase, each child was asked to identify the elements on the screen and later the goal of the task was presented as follows: *"Each element at the bottom of the screen should be located with their respective element at the top part.*

Table 1.
Cognitive planning coding scheme

N	Category	Description	Performance
1	IE Selection of an isolated element	Not evidence of planning	One reference element. No correspondence (e.g. Painter)
2	PS(C) Partial sequence without adjustment of correspondence	Partial planning based on the relationship between elements	Two reference elements, one correspondence (e.g. Doctor/Painter-pot)
3	PS Partial sequence with adjustment of correspondence	Partial planning based on the correspondence between elements	Three reference elements, two correspondences (eg. Pot-cook, Painter-brush)
4	GS(C) Global sequence without adjustment of correspondence	Global planning based on the relationship between elements	Four reference elements, three correspondences (e.g. Doctor- stethoscope, Cook-pot, Painter-brush)
5	GS Global sequence with adjustment of correspondence	Global planning based on the correspondence between elements	Four reference elements, four correspondences (e.g. Doctor- stethoscope, Cook-pot, Painter-brush

To start, you can only pick an element from the bottom by entering the element that is above. Think carefully from which element of the top part you want to start in order to pick the element of the bottom that you want to locate. Remember that at the end, all the elements at the top should have their corresponding match at the bottom". When the child chose a starting reference element, the respective bottom element was available to be matched with an element at the top. For example (see Figure 1), if a child decided to start with the cook, then he would have access to the brush and later the child would decide on which top element the brush should be located. For the ideal solution, the computer generated an automatic initial matched element (see the element under the fireman in Figure1). After the child finished matching the elements on the screen, the researcher asked him/her to count how many matches had been done. At the end of the attempt the researcher said to the child: "Congratulations! You have placed X elements!". At the end of each game session, the child received a sticker as a reward for his participation.

Categories of Analysis

A coding scheme for the use of cognitive planning based on the possible combination of elements on the screen was created. This coding scheme involves five categories (scored from 1 to 5) grouping the performances of the children according to the complexity of the use of cognitive planning. Using these categories as an ordinal scale, the children's performances were scored. The categories indicate the characteristics of anticipation and the consideration of future states to achieve the goal. For instance, the selection of an isolated element indicates the absence of anticipation, and is scored as zero (0). In contrast, a complex performance of anticipation that shows the selection of an ordered sequence of the correspondences of all the elements is scored as five (5) (see Table 1).

Data Analysis

The data analysis starts with an initial characterization of the sample's performance and later with the focus on the analysis of the two case studies. These cases representing the main performances of the sample are the most important focus on the analysis of the short-term development of cognitive planning.

First, the performance of the sample of 45 preschoolers was carried out using a cluster analysis. This procedure compares the trajectories of all the children in order to identify the similarities and differences between them. As a result, this analysis provides differentiated clusters (groups) of the children's trajectories that enabled the selection of the case studies. In this phase of data processing, other statistical analyses were carried out as follows: In order to establish whether the distribution of scores obtained by the children corresponded or not to a uniform distribution, a Chi-square test (X^2) for scores obtained on the total of the 16 screens of the game was carried out. It is assumed that if children's behaviors occur at random, scores of their performances must show a uniform distribution (i.e. a normal distribution).

Table 2.
Cluster analysis of the total sample of children

Sample	Cluster 1	Cluster 2	Cluster 3
Children from city 1	8	13	1
Children from city 2	9	14	0
Total	17	27	1

Table 3.
Significance of scores distribution for each scenario

Scenario	P value			
	Screen 1	Screen 2	Screen 3	Screen 4
Thematic	.000**	.001*	.002*	.000**
Daily activities	.000**	.000**	.003*	.131
Entertainment	.007	.000**	.000**	.000**
Animals	.010	.003*	.000**	.053

Note. Significant at $^{*}p > .01$, $^{**}p < .01$
Selection of the Case Studies

Regarding the participants, the sample of preschool children corresponds to two different cities in Colombia (City 1=22 children and City 2= 23 children) and the results between the two cities do not show differences in the performances of the four scenarios of the task.

Second, the analysis lies in the description of the trajectories of cognitive planning. A case study was chosen from each resulting cluster of the previous analysis in order to illustrate and represent the performance of the sample. The analysis of the case studies was carried out with the State Space Grid technique (SSG, Hollenstein, 2007; Lamey, Hollenstein, Lewis, & Granic, 2004) to identify patterns in the intra-individual trajectories of planning. The SSG represents the data (ordinal or categorical) into a temporal sequence, showing the changes between the predetermined categories. In this study, the SSG consists of a grid with the five categories of planning. The cells in the grid represent the different space states in which the performance of the child emerged in a particular time. Therefore, the space states depict the five categories of planning on two axes (X, Y). Each dot on the grid represents the performance of a child from one attempt to the next one (trial, trial + 1) according to the planning categories. The resulting trajectory of the child's behaviors is plotted as a sequence of points connected with a line, showing the changes in the use of planning within a session.

RESULTS

Scores' Distribution of the Sample

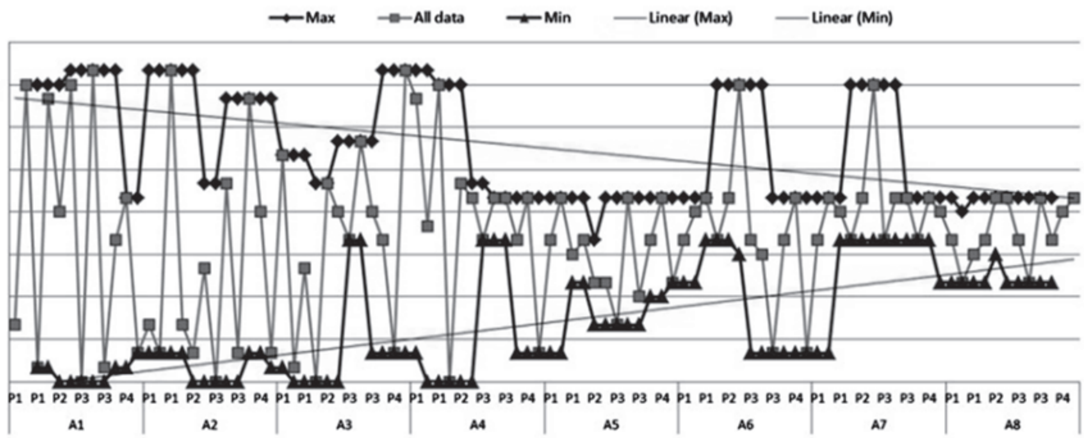
The results of the chi square test (see Table 3) showed that for thirteen (13) out of sixteen screens (81.25%), a non-uniform distribution of the scores was found at a confidence level of 99.99% or greater. In two (2) out of the sixteen screens (12.5%), a non-uniform distribution was found at a level of 90% confidence. Only for one screen out of sixteen (6.25%), the non-uniformed distribution was present at a confidence level of 86.9%. These results indicate that it is unlikely that the performance of children solving the task was due to chance.

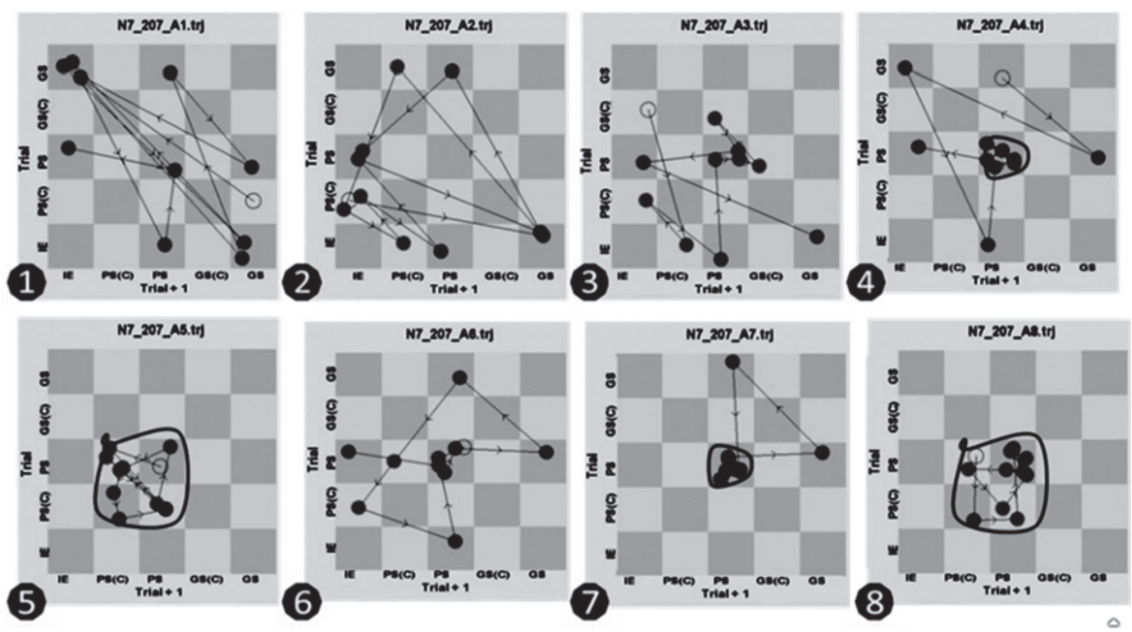
Table 2 shows the results of the cluster analysis carried out with the 45 children of the sample of the two cities. In total, three clusters of children were identified. The table describes how many children per city were involved in each cluster. Cluster 1 with 17 children and cluster 2 with 27 children concentrated almost the total of the sample, while cluster 3 only included one child. In consequence, each case study was randomly selected from cluster 1 and 2 respectively. The two selected cases will be identified as "Felipe" from cluster 1 and "Alejandro" from cluster 2.

Analysis of the Short-term Cognitive Planning Trajectories by Using State Space Grid (SSG)

The short-term analysis of cognitive planning of two children (Felipe and Alejandro) is based on the sequence of SSG. First, for each case its trajectory is illustrated in order to have a general view of the child's performance, and later a grid for each single game session is presented. The description of the resulting grids provides information about the changes on planning skills that took place along the child's trajectory.

(a) Felipe's case





(b) Alejandro's case

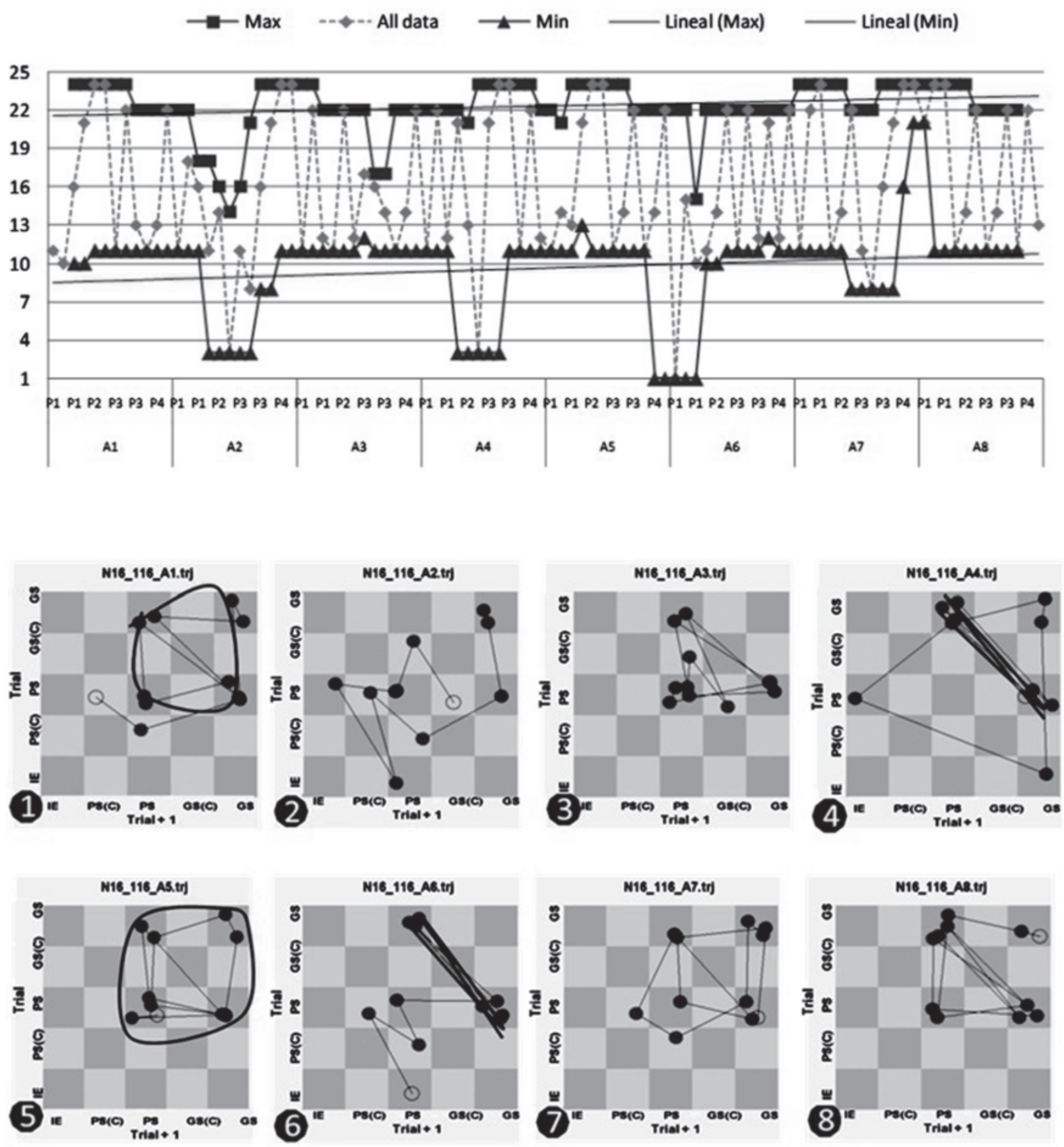


Figure 3. Trajectories and planning performance state space grids (SSG) for Felipe (a), and Alejandro (b). The sequence of the eight grids corresponds to the eight sessions that constitute the trajectory of each child.

Felipe's (Figure 3a) and Alejandro's performances (Figure 3a) showed different trajectories over sessions. Felipe's performance shows high variability for the first three sessions by using most of the planning categories. From session 4, Felipe focuses his planning procedure on the coordination of mean-ends, using partial plans with and without correspondence between elements. In contrast, Alejandro's performance (Figure 3b) is less variable. In sessions 1 and 5, Alejandro was focused on the coordination of sub-goals by elaborating partial global plans with and without correspondence (PS, PSC, GS, GSC). Something similar happened in sessions 7 and 8. However, in sessions 4 and 6 Alejandro turned to use mainly partial (PS) and global (GS) plans.

Identification of Patterns in the Cognitive Planning Performances

The previous analysis with the SSG technique revealed the type of planning behaviors that were more recurrent in the children's performance. From the dynamic systems approach the variations and iteration define the dynamics of the system. The iteration of a state (behavior) over time characterizes the regularities of a system which can lead to a stable or an attractor zone. Because there were not enough behaviors observed per session it is not possible to define the recurrent behaviors as attractors but rather as patterns. Therefore, in the two case studies, intra-individual patterns in the trajectories of planning were identified. Although the children's trajectories are representative of each cluster, it is important to consider that the intra-individual variability of the other cases that are not presented here can include diverse planning patterns (see appendix). Along this line of reasoning, awareness exists that there are more different patterns than on the rest of the sample. However, there is an expectation that the following description of the performances of two children provides an example of the dynamic process in the short-term development of planning skills.

In Felipe's case (cluster 1), cognitive planning was characterized by a *reduction pattern of variability*. Initially, the planning performance is highly variable and later turns to a relative stability. Planning is characterized by partial actions dealing with the presence / absence of correspondence (PSC, PS). In contrast, in Alejandro's case (Cluster 2) cognitive planning showed a *stable pattern of variability*. His performance is characterized by showing low variability and focusing on two types of plans: partial (PS) and global (GS). The main difference between these two patterns of cognitive planning is the level of self-regulation used by the children in their actions to attain the goal and anticipate the future states of the task. In the r*eduction pattern of variability*, the elaboration of plans involved the partial coordination of means-ends relationships while in the *stable pattern of variability*, planning involved a complete coordination and anticipation of the respective correspondences between elements.

As a balance, the two contrasting patterns of cognitive planning emerged as a result of the interaction of two criteria: the constraints of the task and the anticipation of future states. Thus, the observed variations on the elaboration of plans revealed the non-linearity of cognitive plans, and their respective patterns indicate different ways of how children self-regulate their actions. In contrast to the reviewed literature, these children's performances, more than errors, show the processes of self-regulation, of goal-directed actions, and the preliminary anticipation of future states. Furthermore, these results provide additional information about various aspects considered in previous studies: (1) *the prevalence of iterative planning performance as patterns* that depict the tension between partial and global plans. Thus, the planning actions of the children reveal the effort to consider future states in order to select the actions directed to the goal, and (2) the breaking of rules is present in the children's performance; however, along the sessions, the increase of accuracy of their actions indicates that improvement is based on the feedback obtained when making mistakes during the performance of the task. In other words, the change in the child's actions reflects the change in their elaboration of plans.

DISCUSSION

Cognitive planning in preschool children (three and four-years old) is mainly described in the previous studies as a limited process that improves as a result of development and maturation factors. For instance, some of the limitations of planning skills in preschoolers are the breaking of rules, incomplete solutions and lack of ability to consider future states of the task (searching ahead) (e.g. Kaller, et al., 2008, McCormack & Atance, 2011). This characterization of children's performances is based on the task's result rather than on the process required to reach the goal (Matute et al., 2008). Thus, cognitive implications can be smoothed because cross-sectional designs restrict the tracking of emergence processes.

Although these findings show that some children's actions were isolated from the goal (IE), by using a microgenenetic approach the predominant evidence points to the elaboration of plans. Conceiving planning as a future-oriented behavior, these results add information to the findings of Prabhakar and Hudson (2014) about the ability of three-year old children to keep and accomplish multiple goals when they were non-contingent. In this study with preschoolers slightly older (3,5 years) it was found that children were able to plan an ordered sequence of three future goals (correspondences between elements) into a set of 8 elements. This improvement evidences the increased complexity of planning skills with the estimation of future states of the task. In addition, the elaboration plans were diverse in their effectiveness according to the coordination of means-ends giving as a result partial and global plans. As was suggested by Pea (1982), the plans elaborated by children were not only the execution of a previous mental activity, but rather a process adjusted at the same time it was being executed. The microgenetic design used in this study provided the children with the opportunity to perform several attempts in which the adjustment of their behavior was observed depending on the achievement of the task's goal. Thus, planning understood as the anticipation of ordered steps to attain a goal, not only emerged directly into a defined sequence of actions, but also as a process that was corrected during its execution. This characteristic underlines that preschool children are able to adapt their performance to the demand of the task (Rojas, 2006) and self-regulate their action not only until the final result of their actions is observed but also as an ongoing process.

From a dynamic perspective, self-regulation of a system can show repeated interactions that become temporary patterns (Hollenstein & Lewis 2006; Lamey, Hollenstein, Lewis & Granic, 2004; Lewis, Lamey & Douglas, 1999). In the intra-individual short-term development we have observed at least two planning patterns. On the one hand, a pattern with high variability (Felipe's case) combining simple and complex plans that at the end of the sessions was concentrated on the elaboration of partial plans. This indicated that self-regulation of actions increases over time, by establishing sub-goals and adjusting their accomplishment as a future-oriented behavior. On the other hand, a pattern that from the beginning revealed the elaboration of partial and global plans emerged and remained as predominant in most of the sessions (Alejandro's case). According to the findings of this study, it seems that the constraints and the respective feedback of the task played a relevant role in self-regulation of actions and this is evidenced by the adjustment of the children's performance in reaching the goal partially or totally. The planning trajectories of the children reveal that there is not only a single way in which planning emerges, but diverse paths that go beyond the erratic actions or the breaking of rules by showing particular patterns. In this study, variations in the planning trajectories have been identified which by no means exhaust the number of existing patterns. In other words, the intra-individual planning skills showed different non-linear paths that instead of increasing progressively fluctuate over time as part of their own dynamics. And in the middle of all the fluctuations, the regular aspect is that children's trajectories are organized in relation to the consideration of sub-goals, the consequences of their actions and the anticipation of the future state of the task.

As a conclusion, cognitive planning revealed non-linear trajectories in the short-term. This finding supports Linda Smith´s perspective that considers development as a dynamic system evolving over time. This author "recognized the child as an emergent self-organizing system, continuously changing or stabilizing in interaction with an environment, rather than a trajectory programmed by genetics, normative stages, or any other static variable" (cited by Howe & Lewis, 2005, p. 251).

For future research, a relevant point to consider is to explore in more detail the process of change of planning skills into structured and natural contexts. This will provide some bases to identify whether there are contexts that favor the development of plans. Because the elaboration of plans is a process that emerges from age three through five, it is suggested for future studies to follow up these age groups keeping a number of density measurements. Thus, it would be possible to identify how planning patterns related to future-oriented behaviors consolidate over time.

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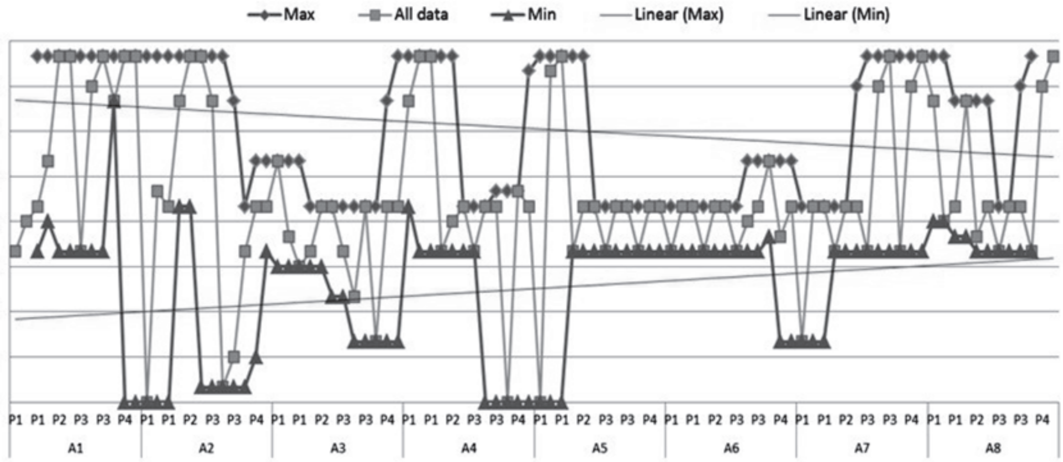
APPENDIX

Example of other case in the cluster 1, as Felipe's case (Case 220)



Example of other case in the cluster 2, as Alejandro's case (Case 219)