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Focusing and Shifting Attention in Human Children (*Homo sapiens*) and Chimpanzees (*Pan troglodytes*)

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Humans often must coordinate co-occurring activities, and their flexible skills for doing so would seem to be uniquely powerful. In 2 studies, we compared 4- and 5-year-old children and one of humans' nearest relatives, chimpanzees, in their ability to focus and shift their attention when necessary. The results of Study 1 showed that 4-year-old children and chimpanzees were very similar in their ability to monitor two identical devices and to sequentially switch between the two to collect a reward, and that they were less successful at doing so than 5-year-old children. In Study 2, which required subjects to alternate between two different tasks, one of which had rewards continuously available whereas the other one only occasionally released rewards, no species differences were found. These results suggest that chimpanzees and human children share some fundamental attentional control skills, but that such abilities continue to develop during human ontogeny, resulting in the uniquely human capacity to succeed at complex multitasking.

Keywords: attentional control, multitasking, focus and shift attention, chimpanzees, human children

Humans are confronted daily by situations that require the ability to coordinate co-occurring tasks and to simultaneously pay attention to the demands of the activities being executed as well as other stimuli, focusing on what is most relevant and filtering out what is extraneous. For example, when driving, one must pay attention to the mechanics of the primary action itself (steering, shifting, accelerating, breaking, etc.) as well as additional chosen activities such as listening to music, engaging in conversation or using the phone, and external stimuli such as pedestrians, bikers, traffic lights and sign boards. Even if such flexibility in action and attention is advantageous for any species, humans seem unique in the degree of flexibility demanded and the prevalence of situations which require such coordination. Thus, it is not surprising that this ability has been intensely studied in human children and adults by researchers interested in various phenomena referred to as: multitasking, task switching, divided attention or dual-task performance, and attentional control (e.g., Diamond, 2013; Irwin-Chase & Burns, 2000; Jersild, 1927; Monsell, 2003; Oswald et al., 2007; Pashler, 2000; Salvucci, 2005; Shallice & Burgess, 1991; Spink et al., 2008). It has been shown that human self-regulatory abilities, like attentional control, develop gradually during childhood, with a sharp increase between 3 and 5 years of age (e.g., Buss & Spencer, 2014; Davidson et al., 2006; Diamond, 2002; Dowsett & Livesey, 2000; Espy, 1997; Herrmann et al., 2015; Klenberg et al., 2001; Kochanska et al., 2000; Kopp, 1989; Kopp & Neufeld, 2003; Luciana & Nelson, 1998; Mischel & Mischel, 1983; Müller et al., 2006; Murphy et al., 1999; Vlamings et al., 2010; Zelazo et al., 2003; Zelazo et al., 2004).

In comparison to the broad literature on humans, very little is known about this ability in nonhuman primates, or about the evolutionary roots of this important regulatory system. In recent years, there have been some studies investigating task switching abilities in rhesus macaques (Avdagic, Jensen, Altschul, & Terrace, 2014; Moore et al., 2005; Stoet & Snyder, 2003, 2007) using similar set shifting paradigms as those developed to study human children. The findings are not consistent across studies and the answer to the question of whether rhesus macaques differ in basic ways from the pattern of behavior reported in studies of human cognition remains unclear. Furthermore, these studies were based on learning an arbitrary rule first and none of these studies directly compared human children with nonhuman primates (but see Caselli & Chelazzi, 2011 for comparison with adults), and so far a comparison with our closest living relatives, the great apes, is lacking.

A few experimental studies have investigated other self-regulatory abilities like inhibitory control in great apes (Amici et al., 2008; Beran et al., 1999; Evans & Beran, 2007), and a few

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have examined how great apes compare to humans (Rosati et al., 2007; Vlamings et al., 2010). Apart from these studies on inhibitory control, there has only been one human–ape comparative study that also focused on other aspects of self-regulation, like attentional control. Herrmann et al. (2015) compared children at 3 and 6 years of age with chimpanzees on a battery of reactivity and self-control tasks. In this systematic comparison, 3-year-old children and chimpanzees were very similar in their abilities to inhibit an impulse for immediate gratification or to repeat a previously successful action when it is not applicable anymore as well as in their attentional control by resisting attending to a distracting noise and quitting in the face of repeated failure. Six-year-old children on the other hand were more skillful than either 3-year-olds or chimpanzees at inhibitory and attention control. However, the attentional control tasks in this study investigated only the ability to focus on a single task and the behavioral responses could be to a large extent driven by emotion instead of by cognition. Furthermore, it has been suggested that chimpanzees have difficulties monitoring and shifting attention between a large number of simultaneous tasks and that this ability might be a uniquely human capacity (Savage-Rumbaugh, 1991; Spink et al., 2008).

Therefore, the first aim of this study was to identify developmental stages in the ability to focus and shift one's attention by testing 4- and 5-year-old human children, the developmental period at which the reported increases in self-regulatory behavior have been shown. The second aim was to compare one of humans' two closest relatives, chimpanzees (*Pan troglodytes*) to the human ontogenetic trajectory. In contrast to previous research, the current tasks are not based on any previously learned arbitrary rule but instead on more natural behaviors in the context of food acquisition for both species. In Study 1, we presented the subjects with a task in which they had to monitor two identical apparatuses from which food was randomly released. To be successful, subjects had to sequentially switch between the two to collect the rewards. In Study 2, subjects were required to prioritize attending to one of two different apparatuses: one that had food available the entire time and one that only occasionally released food.

Study 1

Method

Participants. Participants were twenty-seven 4–5-year-old children (twelve 4-year-olds (eight girls) and fifteen 5-year-olds (eight girls) from one rural kikuyu school, Kabanga in Laikipia, Kenya. All participants spoke Kikuyu as their first language. The children were tested individually in one of their school classrooms. In addition, 26 chimpanzees (14 females; 9 to 26 years of age) participated in this study. The chimpanzees lived at the Ngamba Island chimpanzee sanctuary, Lake Victoria, Uganda. All apes are orphans, were born in the wild, and came to the sanctuary after being confiscated from the illegal bushmeat and pet trade. They were all raised by humans in a highly comparable way, living together with peers after arriving at the sanctuary. The chimpanzees (except two individuals) had access to a tropical forest (40 hectares) during the day. They were never food deprived for any reason and their diet (i.e., the food which was available in their enclosures) was supplemented with a combination of additional fruits, vegetables, and other species appropriate foods.

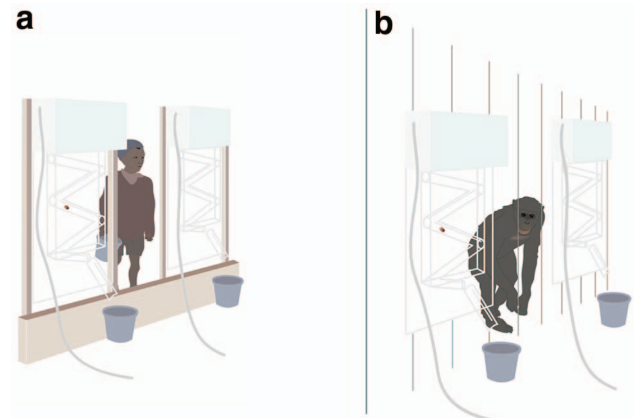

Figure 1. The experimental set-up of Study 1 for human children (a) and chimpanzees (b). See the online article for the color version of this figure.

Apparatus. Two identical Plexiglas apparatuses, each consisting of a Plexiglas tube slide (136 cm long, diameter 5 cm (see Figure 1) through which peanuts can roll down were used. Peanuts were placed in an opaque box, which included five baiting compartments, mounted on top of the slide. The experimenter could pull a rope that controlled the release of peanuts from the baiting compartments into the tube slide. The first pull on the rope moved the first compartment over an opening in the tube and allowed peanuts to roll down. A second pull emptied the second compartment and so on. At the end of the slide the peanuts fell into a second Plexiglas tube which opened into a bucket either outside the chimpanzee room or on the nonaccessible side of the apparatus for the children. The peanuts could be redirected and made accessible by subjects tilting the tube toward them. This allowed the peanuts to be collected in a small bucket (children) or by mouth (chimpanzees). After subjects released the tube, it flipped back to its original position, in which peanuts are inaccessible. The apparatuses were either attached to bars (chimpanzees) or on stands, 106 cm from each other. The experimenter sat on the opposite side of the apparatus from the subject. The experimenter's side was separated from the subject's side by either bars or barriers which prevented subjects from accessing the pulling mechanism and the lost peanuts.

Procedure. Subjects were individually tested by a female experimenter (E) in a classroom at the child's school or in their holding facility (chimpanzees). The study consisted of a familiarization phase and 3 conditions (slow, medium, and fast).

Familiarization phase. To familiarize the subjects with the apparatus, the experimenter inserted one peanut at a time in one of the two apparatuses. The experimenter also showed the subject how to tilt the tube in order to successfully collect the peanuts. Subjects had to reach a criterion of four successful trials in a row before moving to the second apparatus. The order of the apparatus familiarization was counterbalanced across subjects. After reaching criterion with both apparatuses, subjects were tested in the first test condition (slow).

Test phase. Before each testing day, subjects again received familiarization trials until they successfully collected peanuts, by tilting the tube at the critical time, on three consecutive trials from each apparatus. Each trial started with E baiting the compartments in both apparatuses with peanuts and by centering the subject in the middle between both apparatus by feeding them a peanut (chimps) or telling them to start from there (children). E sat down on a small chair between both apparatuses holding the apparatuses' ropes, one in each hand. Each trial included six events in which peanuts were released from the opaque box and rolled down the slide of one of the two apparatuses. The events were spread out across a given trial length and counterbalanced across apparatuses with three events on the left and three events on the right apparatus with no more than two events in a row on a given side. To maximize the success rate, subjects had to switch between both apparatuses whenever peanuts were released from one of them. Subjects received four trials (24 events) per day and condition.

Slow. All subjects first participated in two sessions, one on each of two days in the slow condition which led to eight trials in total. Each trial was 2 min long and six events were randomly spread within this duration. The interevent intervals varied between 10 s and 35 s and were thus rather long making the task less demanding. The number of peanuts released at each event varied between one and three pieces by controlling for the same number released from each apparatus. Subjects who were successful in 75% or more events combining both testing days, continued with the medium and fast conditions which were more challenging in terms of a subject's ability to switch between apparatuses.

Medium and fast. 18 out of 27 children and 15 out of 26 chimpanzees passed the criterion of 75% success rate in the initial slow condition and participated in the medium and fast conditions. The trial length for the medium condition was 1 min (with interevent intervals between 5 s and 15 s) and for the fast condition 30 s (with interevent intervals between 3 s and 7 s). As in the slow condition, six events were randomly spread within these durations. During each event only one peanut was released.

Coding and Reliability. The number of successful events was coded. "Success" required subjects to have tilted the tube at the critical time to be able to receive at least one peanut from the number released at a time. To compare the performance of children and chimpanzees in the three conditions, Mann–Whitney-*U* tests were used. To compare subject's performance in the slow condition across sessions, Wilcoxon's tests were used. In addition, to investigate the influence of age Spearman correlations were used. In case of a significant influence of age in human children, we compared the chimpanzee data with the two human age classes separately, using Mann–Whitney-*U* tests. All statistical tests were two-tailed.

Interobserver reliability for children (slow: intraclass correlation [ICC] $= .998$; $p < .001$; medium: ICC $= .996$; $p < .001$; fast: ICC $= 1$; $p < 0\ .001$) and chimpanzees (slow: ICC $= .999$; $p < .001$; medium: ICC $= 1$; $p < 0\ .001$; fast: ICC $= 1$; $p < 0\ .001$) was excellent.

Results

Figure 2 presents the percent of successful events across sessions, conditions, and species.

Slow. Human children were more successful in the first session than chimpanzees (Mann–Whitney *U* test: $z = -1.979$, $p = .048$) but not in the second (Mann–Whitney *U* test: $z = -0.752$, $p = .458$) or when both sessions were combined (Mann–Whitney *U* test: $z = -1.727$, $p = .085$). A significant increase in success in

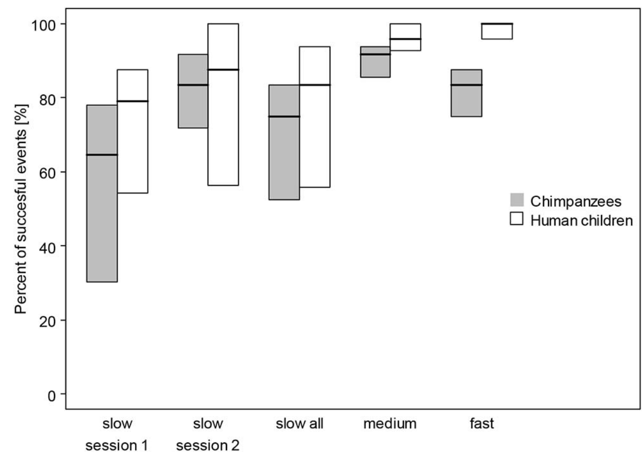

Figure 2. Percent of successful events across sessions for each species of Study 1. Median and interquartile range are given.

subjects' performance between the two sessions for both species was detected (human children: Wilcoxon's test: $z = -2.278$, $p = .023$; chimpanzees: Wilcoxon's test: $z = -3.833$, $p < .001$). Finally, we found that age had a significant influence on each species performance. 5-year-old human children were more successful than 4-year-olds (slow all: $r = .489$, $p = .01$, $n = 27$) whereas chimpanzees were less successful with age (slow all: $r = -0.427$, $p = .03$, $n = 26$). Interestingly, chimpanzees did not differ overall and in both sessions separately from the 4-year-old human children (Session 1: $z = -0.346$, $p = .739$; Session 2: $z = -1.151$, $p = .257$; overall: $z = -0.346$, $p = .739$). However, 4-year-olds and chimpanzees were less successful than the older children (4-year-old children: Session 1: $z = -2.453$, $p = .013$; Session 2: $z = -2.351$, $p = .018$; overall: $z = -2.492$, $p = .041$; chimpanzees: Session 1: $z = -2.712$, $p = .006$; Session 2: $z = -2.145$, $p = .031$; overall: $z = -2.972$, $p = .003$).

Medium and Fast. Human children were more successful than chimpanzees in both conditions (Mann–Whitney *U* test: medium: $z = -2.549$, $p = .010$; fast: $z = -3.831$, $p < .001$). As in the slow condition, we found that age had a significant influence on the children's performance in the medium condition but not in the chimpanzees. Five-year-old human children were more successful than 4-year-olds ($r = .493$, $p = .038$, $n = 18$). As in the previous condition, chimpanzees did not differ from the 4-year-old human children in the medium speed ($z = -0.158$, $p = .898$). However, 4-year-olds and chimpanzees were less successful than the older children (4-year-old children: $z = -2.033$, $p = .041$; chimpanzees: $z = -3.352$, $p < .001$). Age had no significant effect in the fast condition.

Discussion

The current study showed that 4- and 5-year-old human children's and chimpanzee's ability to focus and shift attention differed in important ways. Overall, human children were more successful in monitoring and switching from one apparatus to the other than chimpanzees. But this initial difference in the slow condition disappeared after having more experience with the task. Interestingly, the 4-year-old children were similar to the chimpanzees when the events followed each other at a slow or medium speed but were less successful than the older children. However, after increasing the speed to six events per 30 s, no age effect was detected and human children outperformed chimpanzees. This age difference is consistent with previous research showing that human self-regulatory abilities, like attentional control, increase between 3 and 5 years of age (e.g., Buss & Spencer, 2014; Davidson et al., 2006; Diamond, 2002; Dowsett & Livesey, 2000; Espy, 1997; Herrmann et al., 2015; Klenberg et al., 2001; Kochanska et al., 2000; Kopp, 1989; Kopp & Neufeld, 2003; Luciana & Nelson, 1998; Mischel & Mischel, 1983; Müller et al., 2006; Murphy et al., 1999; Vlamings et al., 2010; Zelazo et al., 2003; Zelazo et al., 2004). In contrast to the increase in attentional control with age in human children, no clear age pattern emerged for chimpanzees. In one condition (slow) however, chimpanzees did show a decrease in performance with age. The reason for this opposite effect in comparison to children is not entirely clear and needs further investigation.

In addition, this study supports the findings by Herrmann et al. (2015), in which chimpanzees showed similar inhibitory and attentional control skills to younger children but differed in important ways from older children. Whereas in Herrmann et al. (2015), subjects had to selectively focus their attention on one apparatus, in the current study, subjects had to focus on multiple apparatuses. To be successful, subjects had to inhibit remaining at a previously rewarding apparatus by shifting their attention to the more relevant apparatus at a particular moment. However, this task was probably less demanding in comparison to previous research on task switching in children or other primates (e.g., Avdagic et al., 2014; Caselli & Chelazzi, 2011; Crone et al., 2006; Davidson et al., 2006; Diamond, 2002; Luciana & Nelson, 1998; Moore et al., 2005; Stoet & Snyder, 2003, 2007; Zelazo, Craik & Booth, 2004). Subjects were never presented with conflicting information/rules at a time in which they had to switch from one set of rules to another but instead only had to physically change locations depending on the occurring stimuli.

To increase the inhibitory and shifting attention demands, we conducted a second study. The aim was to present subjects with two different tasks at the same time which cannot be solved in succession as in Study 1. To be successful, subjects not only had to monitor two locations at the same time but had to shift their attention from an already rewarding task which was available throughout the trial and to which they could return to anytime, to a task which was only available occasionally, in order to maximize their success rate.

Study 2

Method

Participants. Participants were the same from the medium and fast conditions of Study 1 except for one 4-year-old girl and one chimpanzee who stopped participating during the study ($n = 14$ (chimpanzees) and $n = 17$ (human children)).

Apparatus. In addition to one Plexiglas tube slide from Study 1, a table (Platform: 60 × 40 cm) was used (see Figure 3). For both species, there were four rows of wires attached to the platform that served as little obstacles. Peanuts were placed on the table behind the wires and subjects received a stick (35-cm long) to rake the peanuts within reach. The table was placed approximately 50 cm next to the tube platform. For chimpanzees, the table was placed outside of the room against the bars. For children, a sliding platform (80 × 50 cm) was attached to the child's side of the table which prevented the children from picking up the peanuts by hand and let the peanuts slide toward them after being raked up to the end of the table.

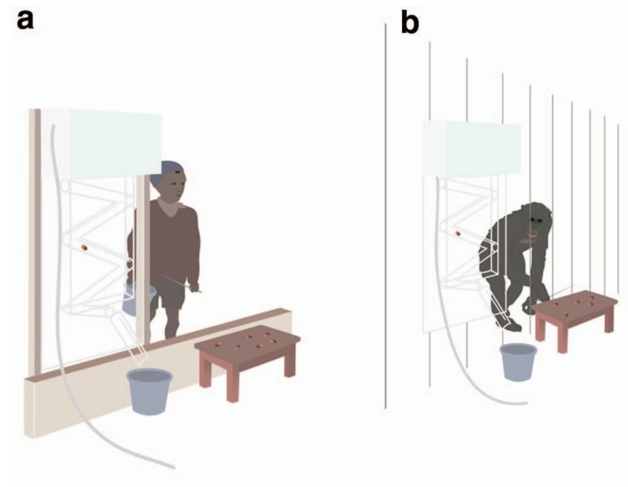

Figure 3. The experimental set-up of Study 2 for human children (a) and chimpanzees (b). See the online article for the color version of this figure.

Procedure. Study 2 consisted of a familiarization phase for the table, an apparatus understanding phase and a test phase of two sessions.

Familiarization Phase. To familiarize the subjects with the new table apparatus, the experimenter placed 12 peanuts on the table and gave the subjects a stick. The subjects were allowed to rake the peanuts within reach for 1 min. Subjects only proceeded to the next step if they were successful in using the tool.

Apparatus understanding. Before subjects participated in the test session, they had to demonstrate an understanding of the apparatus. They were presented with three peanuts on the table, which they had to successfully retrieve with a stick. In addition, they were presented with the tube apparatus alone. The experimenter inserted one peanut at a time in the tube apparatus and subjects had to reach a criterion of three successful trials in a row out of six trials before moving to the test session. The order of the two apparatuses was counterbalanced across subjects.

Test phase. All subjects participated in two sessions of four trials each on 2 days. Each trial started with E baiting the compartments in the tube apparatus and placing eight peanuts on the table. Then E gave the stick to the subjects at the table. E sat down on a small chair between both apparatuses holding the rope of the tube apparatus in one hand. Each trial included four tube events in which two peanuts were released from the opaque box and rolled down through the tube. The events were spread out across the 1 min trial length.

Coding and Reliability. A score for successful switches between apparatuses was calculated. In each trial, eight potential switches were possible, and in each session, 24 switches were possible. A successful switch was coded when the subject received the bait from the tube or after a tube event the subject returned to the table. To compare the performance of children and chimpanzees Mann–Whitney-*U* tests were used. To compare subject's performance across sessions, Wilcoxon's tests were used. In addition, to investigate the influence of age, Spearman correlations were used. All statistical tests were two-tailed. Interobserver reliability for children (ICC = 1; $p < .001$) and chimpanzees (ICC = .994; $p < .001$) was excellent.

Results

Figure 4 presents the number of successful switches across sessions and species. Human children and chimpanzees did not differ in their number of successful switches (Mann–Whitney *U* test: Session 1: $z = -0.856$, $p = .403$; Session 2: $z = -0.658$, $p = .522$; overall: $z = -0.855$, $p = .404$). No significant increase in successful switches in subjects' performance between the two sessions for both species was detected (human children: Wilcoxon's test: $z = -1.024$, $p = .306$; chimpanzees: Wilcoxon's test: $z = -1.192$, $p = .233$). Finally, we also found no age effect for either species.

Discussion

In contrast to Study 1, the current study did not reveal any species differences in the ability to focus one's attention and then switch between two tasks in order to maximize the success rate. There was also no significant increase in switches across sessions. It is difficult to compare this study with previous experimental designs from other researchers, because the methods used varied greatly. In standard task switching paradigms, children or monkeys had to switch from following one set of rules to another set by inhibiting their previous learned and successful response (e.g., Avdagic et al., 2014; Caselli & Chelazzi, 2011; Crone et al., 2006; Davidson et al., 2006; Diamond, 2002; Luciana & Nelson, 1998; Moore et al., 2005; Stoet & Snyder, 2003, 2007; Zelazo, Craik & Booth, 2004). In contrast, this study was not based on any previous learned arbitrary rules but instead on more natural behavior. Subjects were required to prioritize between two different actions, raking food within reach which was available throughout the trial or manipulating a tube in case food was released which only occasionally occurred. To maximize success, the best strategy is to focus on the raking task until the second event occurred, then to switch to the tube and after receiving the reward to switch back to the initial task. The rationale for this method, in contrast to previously used methods, was to model situations which are not only quite common in humans but also in chimpanzees (e.g., while foraging and making decisions between continuing to eat fruits or leaves or to hunt when the opportunity arises).

General Discussion

The present studies examined the ability of 4- and 5-year-old human children and chimpanzees to focus their attention on multiple apparatuses at the same time and to shift their attention to the task of greater relevance at a given time. In Study 1, the overall finding was that human children were more successful in monitoring and sequentially switching from one apparatus to a second one than chimpanzees. However, in the easiest condition, this initial difference disappeared after subjects had more experience with the task. In line with previous research (e.g., Buss & Spencer, 2014; Davidson et al., 2006; Diamond, 2002; Dowsett & Livesey, 2000; Espy, 1997; Herrmann et al., 2015; Klenberg et al., 2001; Kochanska et al., 2000; Kopp, 1989; Kopp & Neufeld, 2003;

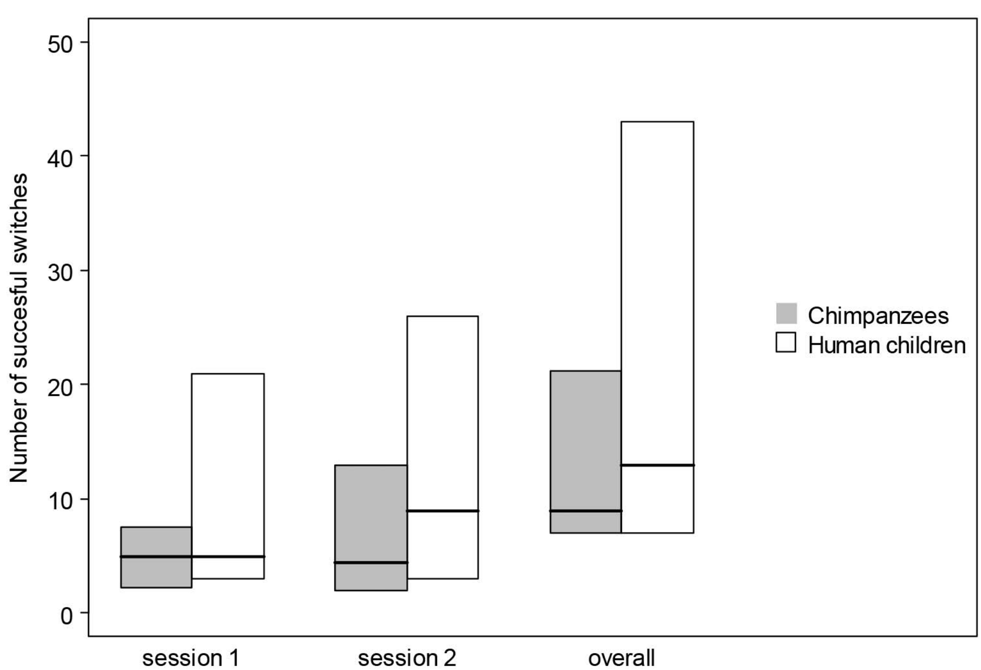

Figure 4. Number of successful switches across sessions for each species. Median and interquartile range are given.

Luciana & Nelson, 1998; Mischel & Mischel, 1983; Müller et al., 2006; Murphy et al., 1999; Vlamings et al., 2010; Zelazo et al., 2003; Zelazo et al., 2004) we also detected significant developmental changes in human children, with 4-year-old children being less skillful than 5-year-olds. Interestingly, chimpanzees were as skillful as the younger children in two out of three conditions. No clear age pattern emerged in the case of chimpanzees. If anything, chimpanzees showed a decrease in performance with age (but only in one condition). To gain a better understanding of the developmental patterns of both species, future studies should investigate a bigger sample size of a wider age range.

In Study 2, in which subjects had to switch between two different tasks, human children were as successful as chimpanzees. These mixed results across studies could be a result of differences in task demands. To be successful in Study 1, subjects had to monitor two apparatuses at the same time but only to find out which apparatus is about to deliver a reward because only one device provided a reward at a time. Hence subjects could solve the task by attending to the relevant apparatus in succession. In Study 2, however, subjects had to monitor two different apparatuses, and to maximize their success rate, they had to shift their attention from an already rewarding task (raking food within reach) which was available throughout the trial and to which they could come back anytime, to a task which was only available occasionally. Therefore, it might be that subjects were as good in focusing and shifting their attention in both studies, but the second study was much more demanding on their inhibition skills. Subjects had to prioritize attending to the tube apparatus whenever a reward was delivered and then had to switch back to their safe and always available resource. One might argue that chimpanzees and 4- and 5-year-old human children show similar skills when taxed by this additional demand. In addition, because Study 2 followed Study 1, there may have been a learning effect. In combination with possible preferences for one apparatus/action, for example, the table/raking (however not the more familiar tube apparatus from Study 1), this might be the reason for the different results. Future research on task switching behavior between two or more tasks in a similar ecologically valid context (e.g., food acquisition) is needed to fully understand the similarities and differences across species.

In general, our findings from Study 1 are supported by a previous comparative study by Herrmann et al. (2015), in which chimpanzees and 3-year-old children showed similar inhibitory and attentional control skills but differed in important ways from older children.

The ability to focus one's attention on multiple events at the same time and to shift attention to tasks of higher priority is advantageous to all individuals because it allows one to flexibly adapt to changes in the environment. Some fundamental skills of attentional control are already present in young children and chimpanzees. However, this ability gradually develops during human ontogeny and results in the uniquely human ability to monitor and shift attention between a large number of simultaneous tasks, a skill continuously required when navigating human daily life (Savage-Rumbaugh, 1991; Spink et al., 2008).

The current study—together with Herrmann et al. (2015)—is the first to systematically compare human children to their closest living relatives on their attentional control abilities. Our results provide important first steps in understanding the evolutionary roots of humans' impressive skills of multitasking. Future research should focus on more diverse tasks provided in different contexts and should include other nonhuman ape species, which would help us to advance our knowledge about this important regulatory system.

References

Amici, F., Aureli, F., & Call, J. (2008). Fission-fusion dynamics, behavioral flexibility, and inhibitory control in primates. *Current Biology, 18,* 1415–1419. http://dx.doi.org/10.1016/j.cub.2008.08.020

Avdagic, E., Jensen, G., Altschul, D., & Terrace, H. S. (2014). Rapid cognitive flexibility of rhesus macaques performing psychophysical task-switching. *Animal Cognition, 17,* 619–631. http://dx.doi.org/10.1007/s10071-013-0693-0

Beran, M. J., Savage-Rumbaugh, E. S., Pate, J. L., & Rumbaugh, D. M. (1999). Delay of gratification in chimpanzees (*Pan troglodytes*). *Developmental Psychobiology, 34,* 119–127. http://dx.doi.org/10.1002/(SICI)1098-2302(199903)34:2<119::AID-DEV5>3.0.CO;2-P

Buss, A. T., & Spencer, J. P. (2014). The emergent executive: A dynamic field theory of the development of executive function. *Monographs of the Society for Research in Child Development, 79,* vii, 1–103.

Caselli, L., & Chelazzi, L. (2011). Does the macaque monkey provide a good model for studying human executive control? A comparative behavioral study of task switching. *PLoS ONE, 6,* e21489. http://dx.doi.org/10.1371/journal.pone.0021489

Crone, E. A., Bunge, S. A., van der Molen, M. W., & Ridderinkhof, K. R. (2006). Switching between tasks and responses: A developmental study. *Developmental Science, 9,* 278–287. http://dx.doi.org/10.1111/j.1467-7687.2006.00490.x

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44,* 2037–2078. http://dx.doi.org/10.1016/j.neuropsychologia.2006.02.006

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 466–503). London, UK: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195134971.003.0029

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135–168. http://dx.doi.org/10.1146/annurev-psych-113011-143750

Dowsett, S. M., & Livesey, D. J. (2000). The development of inhibitory control in preschool children: Effects of "executive skills" training. *Developmental Psychobiology, 36,* 161–174. http://dx.doi.org/10.1002/(SICI)1098-2302(200003)36:2<161::AID-DEV7>3.0.CO;2-0

Espy, K. A. (1997). The shape school: Assessing executive function in preschool children. *Developmental Neuropsychology, 13,* 495–499. http://dx.doi.org/10.1080/87565649709540690

Evans, T. A., & Beran, M. J. (2007). Chimpanzees use self-distraction to cope with impulsivity. *Biology Letters, 3,* 599–602.

Herrmann, E., Misch, A., Hernandez-Lloreda, V., & Tomasello, M. (2015). Uniquely human self-control begins at school age. *Developmental Science*.

Irwin-Chase, H., & Burns, B. (2000). Developmental changes in children's abilities to share and allocate attention in a dual task. *Journal of Experimental Child Psychology, 77,* 61–85. http://dx.doi.org/10.1006/jecp.1999.2557

Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology, 89,* 5–82.

Klenberg, L., Korkman, M., & Lahti-Nuuttila, P. (2001). Differential development of attention and executive functions in 3- to 12-year-old Finnish children. *Developmental Neuropsychology, 20,* 407–428. http://dx.doi.org/10.1207/S15326942DN2001_6

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36,* 220–232. http://dx.doi.org/10.1037/0012-1649.36.2.220

Kopp, C. B. (1989). Regulation of distress and negative emotions: A developmental view. *Developmental Psychology, 25,* 343–354. http://dx.doi.org/10.1037/0012-1649.25.3.343

Kopp, C. B., & Neufeld, S. J. (2003). Emotional development during infancy. In R. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 347–374). Oxford, UK: New York: Oxford University Press.

Luciana, M., & Nelson, C. A. (1998). The functional emergence of prefrontally-guided working memory systems in four- to eight-year-old children. *Neuropsychologia, 36,* 273–293. http://dx.doi.org/10.1016/S0028-3932(97)00109-7

Mischel, H. N., & Mischel, W. (1983). The development of children's knowledge of self-control strategies. *Child Development, 54,* 603–619. http://dx.doi.org/10.2307/1130047

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7,* 134–140. http://dx.doi.org/10.1016/S1364-6613(03)00028-7

Moore, T. L., Killiany, R. J., Herndon, J. G., Rosene, D. L., & Moss, M. B. (2005). A non-human primate test of abstraction and set shifting: An automated adaptation of the Wisconsin Card Sorting Test. *Journal of Neuroscience Methods, 146,* 165–173. http://dx.doi.org/10.1016/j.jneumeth.2005.02.005

Müller, U., Dick, A. S., Gela, K., Overton, W. F., & Zelazo, P. D. (2006). The role of negative priming in preschoolers' flexible rule use on the dimensional change card sort task. *Child Development, 77,* 395–412. http://dx.doi.org/10.1111/j.1467-8624.2006.00878.x

Murphy, B. C., Eisenberg, N., Fabes, R. A., Shepard, S., & Guthrie, I. K. (1999). Consistency and change in children's emotionality and regulation: A longitudinal study. *Merrill-Palmer Quarterly, 45,* 413–444.

Oswald, F. L., Hambrick, D. Z., & Jones, L. A. (2007). Keeping all the plates spinning: Understanding and predicting multitasking performance. In D. H. Jonassen (Ed.), *Learning to solve complex scientific problems* (pp. 77–97). Mahwah, NJ: Erlbaum.

Pashler, H. (2000). Task switching and multitask performance (tutorial). In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 277–309). Cambridge, MA: MIT Press.

Rosati, A. G., Stevens, J. R., Hare, B., & Hauser, M. D. (2007). The evolutionary origins of human patience: Temporal preferences in chimpanzees, bonobos, and human adults. *Current Biology, 17,* 1663–1668. http://dx.doi.org/10.1016/j.cub.2007.08.033

Salvucci, D. D. (2005). A multitasking general executive for compound continuous tasks. *Cognitive Science, 29,* 457–492. http://dx.doi.org/10.1207/s15516709cog0000_19

Savage-Rumbaugh, S. (1991). Multi-tasking: The pan-human rubicon. *The Journal of Neuropsychiatry and Clinical Neurosciences, 3,* 417–422.

Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain: A Journal of Neurology, 114,* 727–741. http://dx.doi.org/10.1093/brain/114.2.727

Spink, A., Cole, C., & Waller, M. (2008). Multitasking behavior. *Annual Review of Information Science & Technology, 42,* 93–118. http://dx.doi.org/10.1002/aris.2008.1440420110

Stoet, G., & Snyder, L. H. (2003). Executive control and task-switching in monkeys. *Neuropsychologia, 41,* 1357–1364. http://dx.doi.org/10.1016/S0028-3932(03)00048-4

Stoet, G., & Snyder, L. H. (2007). Task-switching in human and non-human primates: Understanding rule encoding and control from behavior to single neurons. In S. A. Bunge & J. D. Wallis (Eds.), *The neuroscience of rule-guided behavior* (pp. 227–254). New York, NY: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195314274.003.0014

Vlamings, P. H. J. M., Hare, B., & Call, J. (2010). Reaching around barriers: The performance of the great apes and 3–5-year-old children. *Animal Cognition, 13,* 273–285. http://dx.doi.org/10.1007/s10071-009-0265-5

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica, 115,* 167–183. http://dx.doi.org/10.1016/j.actpsy.2003.12.005

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., . . . Sutherland, A. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68,* 11–119. http://dx.doi.org/10.1111/j.0037-976X.2003.00269.x

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