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Executive Functions in Jordanian Children: What Can the Hearts and Flowers Task Tell Us About Development in a Non-Western Context

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ABSTRACT

Understanding executive functions (EFs) development is of high value to global developmental science. Recent calls for a more inclusive and equitable developmental science argue that tasks and questionnaires that are developed using only a subset of the population are not likely to be appropriate for EFs measurement in global contexts unless explicitly tested . Here, we examined a task commonly used to assess EFs in Western populations in a non-Western sample of Jordanian children. We used the Hearts and Flowers (HF) task to examine (a) its value for assessing EFs development in Jordanian children, and (b) whether task performance was associated with socioeconomic variables and parent report of academic achievement, internalizing, and externalizing behaviors measured with the Arabic Child Behavior Checklist. We report data from $N = 93$ 5.5–8.5 year-old Jordanian children. We found the task to be valuable for distinguishing performance among EFs constructs (working memory, inhibitory control, cognitive flexibility) in this cohort. However, there were no age differences in EFs performance, nor any EFs-specific relationship to any of the parent-report measures of EFs-related constructs. Instead, EFs were related to paternal education and location of residence (Jordanian governorate). We discuss these findings in the context of the expansion of developmental science into global contexts and call for special consideration of measurement and generalizability biases in investigations with human subjects.

Childhood is marked by improvements in self-regulation and flexibility in thought and action (Blakey, Visser, & Carroll, 2016; Diamond, Carlson, & Beck, 2005; Robson, Allen, & Howard, 2020; Snyder & Munakata, 2010; Zelazo, 2006). As children navigate novel contexts, receive formal and informal educational instruction, and adopt cultural and social norms, each experience shapes their development. As the field of cognitive development is increasingly encouraged to diversify our samples both locally and globally, we are called to consider our measurement tools and whether they might be biased outside of the Western context in which they were developed (Hruschka, Medin, Rogoff, & Henrich, 2018; Kusi-Mensah et al., 2018; Nketia, Amso, & Brito, 2021; Vaughn et al., 2022). Here we asked whether a task that is commonly used to assess executive functions in Western contexts is similarly useful in non-Western contexts.

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Executive functions (EFs) are a group of cognitive operations that support goal-directed behavior (Badre, 2008; Friedman & Miyake, 2016). These include working memory (WM), inhibitory control (IC), and cognitive flexibility (CF) (e.g., Davidson, Amso, Anderson, & Diamond, 2006; Friedman & Miyake, 2016). Working memory supports the active maintenance and updating of task relevant information, particularly in the presence of competing alternatives for behavior, in service of a task or goal (e.g., Baddeley, 1986; Cowan, 1988; Diamond, 2013). Inhibitory control supports the suppression of prepotent, automatic, or dominant thoughts or actions (Logan & Cowan, 1984; Freidman & Miyake, 2006; Diamond, 2013). Cognitive flexibility is the ability to adapt thoughts and behaviors to changes in one's environment and goals (Diamond, 2013; Miyake & Friedman, 2012; Zelazo, 2006).A wealth of data has shown that EFs have broad value for mental health, well-being, and education. For example, EFs have been found to be associated with academic achievement (Becker, Miao, Duncan, & McClelland, 2014; Clements, Sarama, & Germeroth, 2016; Lawson & Farah, 2017), learning disabilities (Rosenzweig, Krawec, & Montague, 2011), behavioral regulation disorders including ADHD (Nigg et al., 2017), anxiety disorders (Zainal & Newman, 2018), and overall mental health and well-being (Diamond, 2011).

It follows then that understanding EFs development is of high value to developmental science and will likely be a goal of many investigations as the developmental science community increasingly goes global. This highlights the value of careful and unbiased measurements. Most, if not all, EFs tasks have been developed at Western institutions. Beyond that, cognitive tasks of this type have primarily been developed with participation from white, middle-class children and families (Bornstein, Jager, & Putnick, 2013). We argue that the tasks themselves must be vetted for utility and sensitivity in non-Western contexts before any interpretations or theories can be derived from their use. Can we see basic effects of experimental conditions? Are there age effects as might be expected? Do they relate to characteristics of the local culture and community or to parental reports of related constructs?

Here, we will examine a task commonly used to assess EFs in Western populations in a non-Western Jordanian sample of children. We will explore the Hearts and Flowers (H&F) task, developed by Davidson, Amso, Anderson, and Diamond (2006). Since the original paper, the H&F task has been used in an additional 166 separate studies. H&F is a computerized task consisting of three blocks of trials (see Figure 1). In all blocks,

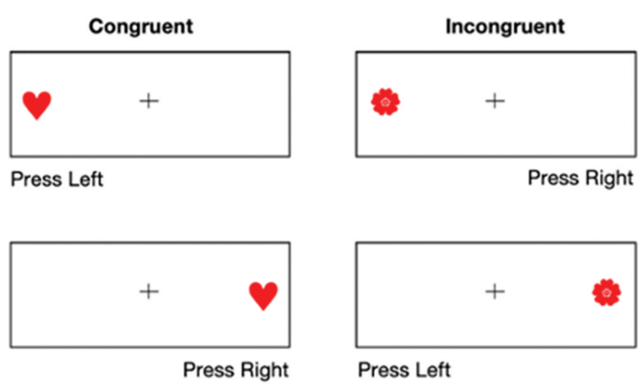

Figure 1. Hearts and flowers stimuli and instructions for congruent and incongruent task blocks.

participants see either a heart and/or flower stimuli that are presented separately on either the right or left side of the screen and are instructed to press a keyboard button in response to a rule. In the Congruent block, participants are instructed to press a button corresponding to the side of the screen where the heart appeared. This block requires the participant to hold one rule in their working memory; press the key on the *same* side that the heart stimulus appears. During the Incongruent block, participants are asked to make a key press on the *opposite* side that the flower stimulus appears. Ostensibly, the Incongruent block requires the participants to (a) hold the new rule in working memory and (b) inhibit the prepotent response to select a key press on the same side that the stimulus appears. Finally, the Mixed block incorporates both the H&F stimuli, and their respective rules. Here, participants must flexibly switch between the two rules. Performance on this block provides a measure of cognitive flexibility in the presence of two competing alternatives for behavior.

Although H&F offers experimental advantages as a task (i.e., requires very little set up; is simple and children across a wide age range can understand it), we do not have evidence of its validity or generalizability for use outside of Western populations, nor an understanding of its generalizability beyond commonly tested communities within Western populations. This is in part because of a historic tendency to not report demographic information in developmental science. Bornstein, Jager, and Putnick (2013) reported that a review of the top five developmental journals found that one-quarter to over two-thirds of the studies inadequately reported race and ethnicity data, 41.4% excluded or insufficiently reported this information, and only reported that the samples were "'predominantly White'" or "'about half minority.'" At the time of our latest literature review, 167 studies implemented the H&F task in 4–10-year-olds. We conducted an informal search of the demographic makeup of these 167 studies. Of the 167 papers, only 24 (14%) fully reported demographic information, 12 (50%) of these 24 publications reported a "majority White" or "majority Caucasian or European" participants as an acknowledgment of the homogeneity of their sample. Additionally, eight (~33%) papers reported income or income-to-needs information. All but one (Zhao et al., 2021) included only Western communities.

Within these Western contexts, H&F results show strong age effects on EFs performance across early and middle childhood. Davidson, Amso, Anderson, and Diamond (2006) showed that for all three blocks, accuracy, lower reaction time, and anticipatory responses all increased over their 4–13-year-old age range. Age-related differences were most apparent in the younger participants. Although the 4- and 5- year-old participants could perform well (above 70%) in the Congruent and even the Incongruent condition, they averaged below 70% in the Mixed block. Six-year-olds in comparison performed well in both the Congruent and Incongruent block and well above 70% in the Mixed block. Consistent with the findings from Davidson, Amso, Anderson, and Diamond (2006), subsequent studies using the H&F task have found that 4- and 5-year-olds perform similarly well on the Congruent and Incongruent blocks (Diamond, Barnett, Thomas, & Munro, 2007b), and there is a distinct improvement beginning at age 6, while Mixed block accuracy improved significantly around 7 years of age (Brocki & Tillman, 2014).

The only study that employed this task in non-Western (Singaporeans and Chinese) samples (Zhao et al., 2021) used it solely as one of many paradigms to create a composite EFs score. No isolated H&F data were reported.

Our sample includes 5.5–8.5-year-old Jordanian children, an age-spread likely to involve performance improvements especially on the Mixed block of trials if this task performs similarly in Western and non-Western contexts. We examined task data for patterns by condition and age. We also asked whether the task was sensitive to socioeconomic variability in the sample. EFs tasks have been reported to be associated with both family income and maternal education in previous Western reports (Amso, Haas, McShane, & Badre, 2014; Hackman, Farah, & Meaney, 2010; Hackman et al., 2014; Hackman, Gallop, Evans, & Farah, 2015; Lawson & Farah, 2017;Ursache, Noble, & Blair, 2015). Of course, these effects may be less likely to hold outside of a Western economy. Nonetheless, task sensitivity to external environmental factors may be valuable for understanding its utility. To that end, we also examined whether the task data were sensitive to parent-report of EFs-related constructs, here measured by The Child Behavior Checklist (CBCL) (Achenbach, 1999; Achenbach & Rescorla, 2000; Achenbach, Dumenci, & Rescorla, 2001). The CBCL has been tested on children in over 30 countries around the world (Ivanova et al., 2007; Rescorla et al., 2007). The CBCL has been directly translated into Arabic and used in Middle Eastern populations (Nehring et al., 2021). General findings on the relationship between the CBCL and EFs include negative associations between EFs and with externalizing problems (McNeilly, Peverill, Jung, & McLaughlin, 2021; Utendale, Hubert, Saint-Pierre, & Hastings, 2011) and higher internalizing (anxious/depressed, withdrawal) problems (Vuontela et al., 2013). Parent report of academic performance is also assessed in the CBCL. EFs have been associated with academic achievement in Western contexts (Lawson & Farah, 2017). Taken together, these data lead us to ask whether we can identify associations between EFs in non-Western communities, as measured by this task, and parent-report of related constructs as measured by CBCL.

Method

Participants

A sample ($N = 105$, 5.4–8.8-year-old children, 57 Male) of Jordanian children in and near Amman, Jordan participated in data collection through their local schools, and through a collaboration with local NGO Taghyeer. Of the total sample, $N = 93$ children contributed full H&F and CBCL data to this analysis. Five children were excluded because they did not contribute either H&F (3) or CBLC (2) data. Of the remaining $N = 100$ participants, an additional $N = 7$ participants were excluded for having more than + 2SDs below the group mean on the Congruent condition accuracy (discussed below) with less than chance (50%) performance. Descriptive statistics for the final sample are reported in Table 2. The Institutional Review Board at Brown University approved all study procedures. Parents signed consent forms approving child participation. Families received the equivalent of $10 USD.

Power and sample size

These data were collected as part of a larger study in Jordan. The sample is largely a convenience sample. Nonetheless, with three age-groups and three conditions, our sample size well exceeds what would be necessary to detect medium effects sizes. We conducted a power analysis using

G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) to calculate the minimum sample size to achieve a power of 95%, which determined that an N of 75 was required.

General country and demographic data

The purpose of this section is to qualitatively contextualize the lived experience of the population from which our sample was drawn. Jordan is a country in the Middle East, bordered by Syria, Israel, the West Bank, Saudi Arabia, and Iraq. Jordan is one of the world's leaders in hosting migrants and refugees from neighboring states and has experienced a 59% increase in population growth driven by the influx of refugees since the onset of the Arab Spring (Jordan's population in 2020 stood at 10.2 million people, 32.90% of whom are below the age of 15). The World Bank has designated Jordan an "upper middle-income country." The economic infrastructure is a mix of free economy and centralized government regulated industry. Jordan's average household income in 2018 was USD 15,856 (Government of Jordan, 2018). Our sample population average income was USD 9,981 (Table 2). Inequality of opportunity (access to services and education) in Jordan is low by international standards and is largely driven by differences between governorates and levels of household head education (Programme, 2015). Our data were drawn from 3 schools. One was from Al-Salt (suburban area) and the other two Amman (urban area). Family income and paternal education were both higher in Al-Salt, which had an average income of USD 15,689, while the two Amman schools had average income of USD 6,466 and USD 5,448.

In 2018, the Jordanian Ministry of Education declared education to be a social right for both men and women. Mean maternal education in our sample was 14.64 years and paternal education 14.17 years (Table 2). Country data indicate that only 13% of children attend preschool and fewer than 3% any childcare setting before the age of 3. In general, 59% attend kindergarten around age 5. Generally, mandatory schooling begins at age 6 and continues for 10 years. This is followed by a 2-year general education high school (16–18 years). Based on outcomes of exams, students then either enter vocation or continue onto college-level studies. The illiteracy rate is 6.7% among people older than 15 years; 9.9% are women and 3.6% are men (Government of Jordan, Department of Statistics, 2019). While education is valued tremendously in Jordanian culture, formal extra-curricular activities (ECA) are less common. Extra-curricular funding is both limited and decreasing, with only 0.3% of the country's total expenditure dedicated to ECA, down from 0.80% in 2011 (Government of Jordan, Ministry of Education, 2020). In our sample, while 93% of parents reported encouraging their children to have regular hobbies, only 24% reported that their children participated in special lessons such as art, music, or sports.

At the organizational/community levels, Jordan is a predominantly Islamic country. The religious and cultural landscape is one that centers around the family. Relationships are reciprocal where the rights of the child are the responsibilities of the parent and the rights of the parent are the responsibilities of the child (Al-Hassan & Takash, 2011; Feliet & Al-Seyyed, 2003). At the interpersonal level, Jordanian children are protected and cherished by their parents and are expected to offer respect and obedience. Fathers are primarily responsible for financial care of the family, whereas mothers care for the household and children (Al-Hassan & Takash, 2011; Feliet & Al-Seyyed, 2003). Mothers in Jordan typically share caregiving responsibilities with female, extended family members, such as grandmothers and aunts of their children. Accordingly, paternal education was more highly correlated with family income, $r(103) = .37$, $p < 0.001$, than maternal education, $r(103) = .26$, $p = 0.008$. Of the families who reported occupation, 50% of mothers reported caring for the household. Culturally, children care for their parents as they age (AFS, 2022). Of the $N = 105$ children, 3.80% (4 children) experienced parents divorcing.

A literature review indicated that parenting styles in Jordan are often progressive, rather than authoritarian (Sabri, 2002). In a study of the values and goals mothers hoped to instill in their children (Al-Hassan & de Baz, 2010), mothers reported emphasis on developing well-mannered, obedient, decent, and loving children. The study also found that mothers placed less emphasis on self-maximization, but when they did, the values were diligence, persistence in schoolwork, and creativity. In their study, Al-Hassan and de Baz found 21.9% (twenty-three) of children had ever been in trouble with a teacher. Less than 6% (six children) had ever received failing grades. In addition, a study investigating father involvement among Middle Eastern countries found that fathers with higher levels of education from the Levant region (Israel, Jordan, Lebanon, and Palestine) were more involved in the details of their children's education (Ridge & Jeon, 2020). Parents in our sample were asked to report any positive or any negative life event that their children had experienced in the last 12 months; no parents indicated exposure to violence. Only two children (of $N = 105$, 5.5–8.5-year-olds, see participants section) experienced a parent going to jail (1.9%).

General procedure

Local Arabic-speaking Jordanian research assistants reviewed consent documents with parents and tested Jordanian children in three local schools in Al-Salt and in the greater Amman, Jordan areas. Recruitment materials were provided in the form of leaflets written in Arabic and distributed to caregivers of the children that attended the schools. Upon consenting to participate in the study, parents were asked to provide demographics information and complete a battery of assessments (including the CBCL) while their child completed a cognitive battery of tasks. The purpose of the broader study was to examine the impact of a Jordanian reading program called We Love Reading on cognitive and literacy development in children. In addition to the H&F task, the battery also included a literacy assessment, a Face Go/NoGo task (Tottenham, Hare, & Casey, 2011), and a recognition memory task (DeMaster & Ghetti, 2013). Task order was counterbalanced across participants. We note here that a subset of the H&F data was used in a non-peer reviewed conference paper that examined within-subjects change in baseline to post-intervention assessment (Dajani, Al Sager, Placido, & Amso, 2020). The data used for this analysis are from the baseline time point.

Hearts & flowers task

The H&F task was presented to participants on a PC laptop computer. Participants were seated in a quiet room, with the laptop placed in front of them. The keyboard of the laptop was covered, with cutouts such that only the two response keys were visible (corresponding to left and right screen responses). Each Congruent and Incongruent condition included a practice block followed by a block of 12 trials. The Mixed block included a total of 33 trials. Each trial was presented for up to 1500 msec, with an inter-trial interval of 1000 msec (total time on task <3 minutes). No feedback was provided by the experimenter after children learned the rules for a given block. All instructions and interactions were in Arabic.

Procedure and instructions specific to the congruent block. The Experimenter explained the rules of the Congruent block in Arabic saying, “First we are going to play the Heart game! When you see a heart on the screen, you are going to press the button that is on the same side as the heart. So, if the heart is on this side (pointed to heart), you press THIS button! (pointed to the button or key on the congruent side).” Children then completed a practice of 4 untimed trials. Each trial lasted as long as it took for the child to make a response. If they did not understand the rules and answered incorrectly, a second practice block was initiated. Children were then told that in the real game, the pictures would go by faster, and allowed a practice block of timed trials (1500 msec). The Experimenter then said, “Great! So now, it’s time to play the heart game for real. Remember to play as fast as you can, but slowly enough that you always press the correct button! Remember, when you see a heart, you press the button on the (Experimenter tried to prompt the child to say ‘same’) side! Are you ready?”

Procedure and instructions specific to the incongruent block. The Experimenter said, When you see a flower, your job is to press the button on the other side of the flower. So, if the flower is on this side (pointed to the flower on the right side of the screen), you press THIS button! (pointed to button or key on the incongruent left side). And if the flower is on this side (e.g., Experimenter pointed to the flower on the left side of the screen), you press THIS button! (Experimenter pointed to the button or key on the incongruent side).” The child again completed an untimed practice block. One additional practice was allowed if the child did not understand the rules. When they were ready to begin, they were reminded, “Remember to play as fast as you can, but slowly enough that you can press the correct button. Remember, when you see a flower, you press a button on the … (Experimenter tried to prompt the child to say ‘other’ along with you) side! Are you ready?”

Procedure and instructions specific to the mixed block. Children were told that it was finally time to play both the heart game and the flower game at the same time. “Remember … When you see a heart, you press the button on the … (tried to prompt the child to say ‘same’) side! And when you see a flower, you press a button on the … (tried to prompt the child to say ‘other’) side!”

The child behavior checklist

The Classic Arabic (MSA) translated CBCL/6–18 was given to parents of the children participating in the study. Although the CBCL is written to be self-explanatory a researcher was available to assist the parents in reading the items aloud. For each problem item, parents were asked to reflect on the past 6 months and determine whether their child demonstrated the behavior outlined in the item. Parents were then asked to respond on a three-point Likert scale. For each item, they have the option to circle “2” if the item was very true or often, “1” if the item was somewhat or sometimes true, or true “0” if the item was not true of their child. For competency items, parents were asked to assess their child's competency in activities pertaining to social interactions, extracurricular activities, and school performance. The checklist consists of 113 items that fall within eight scales (anxious/depressed, depressed, attention problems, somatic complaints, social problems, thought problems, rule-breaking behavior, and aggressive behavior) that group into two higher-order factors (internalizing and externalizing behaviors).

Results

Hearts and flowers condition and age effects in a non-Western sample

Accuracy (percent correct) data were calculated as the sum of correct responses, divided by the total trial number, for each condition. Reaction times (RTs) were computed in milliseconds (msec) for all correct trials and averaged for each condition. Accuracy and RT data were analyzed separately. We first examined the H&F data for any outliers. Of the $N = 100$ participants that completed the CBCL and the H&F task, $N = 7$ participants were excluded for having accuracy scores that were more than 2*SD*s below the group mean on the Congruent condition, with their accuracy also ($M = 31\%$, $SD = 12\%$) below chance (50%) performance.

With respect to H&F accuracy, we conducted a general linear model analysis with the within subjects variable of Condition (Congruent, Incongruent, and Mixed) and the between subjects variables of Age Group (Group 1: 5.5–6.5-year-olds, Group 2: 6.5–7.5-year-olds, Group 3: 7.5–8.5- year-olds) and School Location (Al-Salt, Amman). Table 5 shows correlations between performance and relevant sociodemographic variables. Maternal Education, Paternal Education, and Family Income variables are correlated with each other. Thus, we took a conservative approach and only included in this model those sociodemographic variables that also showed correlations with any of the EFs conditions (see Table 5). Thus, Paternal Education, and Family Income were included in the model as continuous variables.

We found a main effect of Condition, $F\ (2{,}166) = 7.26$, $p < 0.001$, $p\eta^2 = .08$. Figure 2a shows that accuracy is higher for Congruent relative to both Incongruent, $t\ (92) = 9.39$, $p < 0.001$, and Mixed, $t\ (92) = 23.53$, $p < 0.001$. Moreover, the Mixed accuracy was poorer than Incongruent, $t\ (92) = 9.24$, $p < .001$. We found a main effect of School Location $F\ (2{,}83) = 4.16$, $p{=}0.02$, $\eta p^2 = .09$, and of Paternal Education, $F\ (1{,}83) = 4.69$, $p{=}0.033$, $\eta^2 = .05$. With respect to School Location, children in the school in the Al-Salt Governorate outperformed children in both schools in the Amman Capital Governorate (*p*s<.001, Figure 2b). Table 5 shows better performance on all three EFs tasks with higher Paternal Education. Finally, there was not an expected main effect of Age Group, $F(2{,}83) = .334$, $p > .72$, nor an AgeGroup by Condition interaction, $F\ (4{,}166) = .85$, $p{=}0.50$, $\eta p = .02$. We note here that Table 5 shows correlations between income and EFs. However, there was not a main effect of family income nor any interactions of Condition with family income in the analysis. We expect this is because family income differs by School Location (Governorates), $F\ (2{,}90) = 20.92$, $p < 0.001$, $\eta^2 = .32$ and therefore is not a reliable predictor when this variable is included in analyses. The same children participated in a Face Go/NoGo task (taken directly from Tottenham, Hare, & Casey, 2011) whose results are in preparation for full submission in another manuscript. As a manipulation check, we report

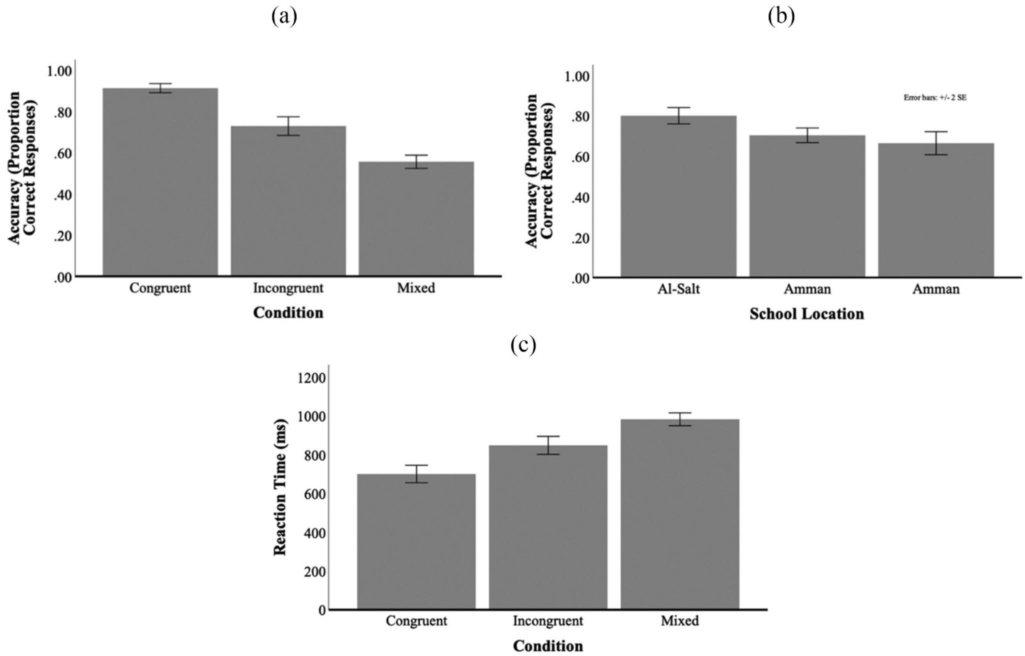

Figure 2. (a) Main effect of condition for accuracy, (b) Main effect of school location for accuracy, and (c) Main effect of condition for RT. Error bars show +/- 2 SEM.

here a metric from this task to show that unlike the H&F task, Go/NoGo task performance positively correlated with Age in this sample. The correlation obtains when we partial out the variance contributed by School Location and Family Income, $r(87) = .29$, $p < .01$.

We conducted a general linear model for RT data (Figure 2c), with a Condition (Congruent, Incongruent, and Mixed) by between subjects variables of Age Group and School Location, with Family Income included as a continuous variable (per correlations indicated in Table 5). This analysis resulted in a main effect of Condition, $F(2,168) = 14.07$, $p < 0.001$, $\eta^2 = .14$. RTs were faster on Congruent than Incongruent, $t\,(92) = 6.60$, $p < 0.001$, and Mixed, $t\,(92) = 13.95$, $p < 0.001$. Performance on Incongruent was faster than on Mixed, $t\,(92) = 6.46$, $p < 0.001$. We did not find a main effect of Age Group $F\,(2,84) = .79$, $p = 0.46$, $\eta^2 = .018$ nor an Age Group x Condition interaction $F\,(4,168) = .86$, $p = 0.49$, $\eta^2 = .02$.

H&F task and CBCL scores

In this final section, we further explore whether there are relationships between EFs as measured by this task and CBCL parent report of Externalizing, Internalizing, and School Competence scores. As noted in the Introduction, studies have indicated relationships between EFs task performance and externalizing problems (McNeilly, Peverill, Jung, & McLaughlin, 2021; Utendale, Hubert, Saint-Pierre, & Hastings, 2011) and internalizing problems as measured on the CBCL (Vuontela et al., 2013). Table 5 shows correlations among variables of interest. Accuracy data show stronger associations with CBCL variables than do RT data. Thus, accuracy was used in analyses.

We ran separate Univariate GLM models with the dependent variable School Competency (Table 6), Externalizing (Table 7), and Internalizing (Table 8) CBCL scores. School Location was included in all three models. Predictors were the three H&F scores (Congruent, Incongruent, Mixed), the other CBCL measures, and sociodemographic data correlating with the specific dependent variable (per Table 5). Tables 6, Tables 7, 8 show results of each set of relationships across EFs. To summarize, there were no associations between EFs scores and any of the CBCL measures. Paternal education was a significant predictor of parent-report of School Competency (Table 6).

Discussion

A shift toward a more equitable and inclusive developmental science not only requires the implementation of new methods and theoretical frameworks, but a scholarly critique of existing findings and practices. Here we asked how a non-Western sample of children perform on the H&F task, a widely used Western-standardized EFs task (Table 1) to determine the utility and fit of the task in capturing underlying constructs of development in the population from which our sample was drawn. We also investigated our sample using a standardized parent report of children's behavior, the CBCL, a standardized, and widely translated measure of behavioral and emotional competencies in children. Results of the analyses suggest that the H&F task is not suitable for use among the population of Jordanian children. Specific findings warrant further discussion.

Overall, our sample of 5.5–8.5-year-old Jordanian children performed consistently with established findings from Western populations on the H&F task with respect to the three blocks/conditions (Davidson, Amso, Anderson, & Diamond, 2006). Children were both slower and performed worse on the Incongruent block compared to the Congruent block, and in the Mixed block compared to both the Congruent and Incongruent blocks (see Figure 2). However, we did not find age-related effects that have been widely reported in the literature. Prior implementation of the H&F task found that children performed better on accuracy and demonstrated lower RTs with age across all three blocks of the task (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, Barnett, Thomas, & Munro, 2007b). These studies also found a statistically significant improvement on both accuracy around age 6 and shorter RTs around the age of 7 (Brocki & Tillman, 2014). Specifically, these studies found that 4- and 5-year-olds perform well (above 70% accuracy) in both the Congruent and Incongruent conditions but below 70% in the Mixed block (Diamond, Barnett, Thomas, & Munro, 2007a), while children 6 years and older perform well (above 70% accuracy) across all three blocks of the task (Brocki & Tillman, 2014; Diamond, Barnett, Thomas, & Munro, 2007b).

In contrast, our investigation did not reveal developmental differences in accuracy or RTs across a similar age range (Tables 2–4). We can interpret this result in one of two ways. Either the H&F task is not sensitive to the *developmental progression* of EFs in this Jordanian population or there is little developmental change between 5.5–8.5 years of age in this population. The latter seems unlikely. Indeed, a study of 4–6-year-old children in Jordan that used the Dimensional Change Card Sorting task found a significant relationship between EFs performance and age (Al-Hmouz & Abu-Hamour, 2017). Moreover, the children tested on the H&F task here also participated in a Face Go/NoGo task (Tottenham, Hare, & Casey, 2011). Table 5 shows that there was a correlation with age in

Table 1. Twenty-four publications that implemented the H&F task and that fully reported demographics information of age, location, and ethnicity.

Authors	N	Age	Location	White/ Caucasian/ European descent	Black or African American	Asian	American Indian/ Indigenous people	Alaskan Native/ Pacific Islander	Asian or Pacific Islander	Biracial/ Multiracial/ Other	Hispanic/ Latino	Included ethnicity in racial breakdown
Wright and Diamond (2014)	96	6-to-10-year olds	Lower Mainland of BC, Canada	52%		28%				20%		N/A
Brocki and Tillman (2014)	117	5 to 14 year olds		68%	4%	3%				16%	6%	Yes
Zaitchik et al., (2014)	79	5–7 year olds		92%	3%						5%	Yes
Ursache, Noble, and Blair (2015)	388	6–12 years olds	Chicago, IL	2.4%	72.3%		1%			2.4%	22.8%	Yes
Ursache, Noble, and Blair (2015)	82	6–12 year olds									25.3%	N/A
Blankson & Blair, (2016	171	$M = 68.85$ months of age, $D = 4.19$		34.2%	20.3%					20.3%	12%	Yes
Finch & Obradović, 2017)	334	7–11 year olds	San Francisco Bay Area								32%	Yes
Hartstein et al., 2018	38	4.5-to-5.5 year olds	greater Amherst, MA area	89.5%						5.25%	5.25%	N/A
Thierry et al., 2018	296	$M = 4.50$, SD $= .32$	large-sized city in the southwestern region of the USA	1%	57%					2%	40%	Yes
Daneri et al., 2018	697	4 year olds	a large, urban setting	21.0%	37%						42%	Yes
Obradović et al., 2018	269	third through fifth graders	San Francisco Bay Area	23%	7%	33%				5%	32%	Yes
Sulik et al., 2018	276	third through fifth graders	San Francisco Bay Area	21%	6%						32%	Yes
McCoy et al., 2019	466	$M = 49.219$, $SD = 7.252$	Chicago, IL	3%	68.7%					3.9%	24.5%	Yes

(*Continued*)

Table 1. (Continued).

Authors	N	Age	Location	White/ Caucasian/ European descent	Black or African American	Asian	American Indian/ Indigenous people	Alaskan Native/ Pacific Islander	Asian or Pacific Islander	Biracial/ Multiracial/ Other	Hispanic/ Latino	Included ethnicity in racial breakdown
McKinnon & Blair, 2019	759	*M* = 69 months, SD = 4 months	12 districts outside a large New England city	72%	2%	4%				15%	8%	Yes
Ren, Lin, and Gunderson (2019)	317	*M* = 8.02 years, SD = .91	a large city in the Eastern United States	18%	45.7%	3.2%	0.6%	0.3%		9.8%	10.10%	Yes
Blankson et al., 2019	198	M age = 58.13 months, SD = 4.04	southeastern part of the United States		100%							N/A
Bardack & Obradović, 2019	813	third through fifth graders	San Francisco Bay area	23%	6%				34%	6%	31%	Yes
Finch et al., 2019	806	third through fifth graders	San Francisco Bay area	23%	6%				34%	6%	32%	Yes
Garcia et al., 2019	558	*M* = 9.90 years old, SD = 0.83 years	San Francisco Bay area	23%	6%				33%	6%	32%	Yes
Tardiff et al., 2020	83	*M* = 76.6, SD = 4.44	Cambridge, MA and surrounding towns	70%	21% combined	21% combined	21% combined	21% combined	21% combined	21% combined	9%	No
Sulik et al., 2020	569	*M* = 9.88 years, SD = 0.83	San Francisco Bay Area	23%	6%				34%	6%	31%	Yes
Guerrero-Rosada et al., 2021	307	*M* = 7.14	city of Boston, MA	27.36%	19.87%	15.64%				6.84%	30.29%	Yes
Romeo et al., 2021	107	*M* = 5.78 years, SD = 0.59 years		5%	36%	2%				3%	54%	Yes
Zhao et al. (2021)	176	from the U.S. (*M* = 6.21, SD = 1.36) China (*M* = 6.39, SD = 1.33) Singapore (*M* = 6.01, SD = 1.29)	USA, China, Singapore	64.76%	6.15%	17.09%	0.19%			5.03%	6.80%	No

this same sample of children in this separate EFs task, indicating that the lack of an age effect is not likely meaningful but instead reflects task by population dynamics.

We also found no relationship between H&F performance and any of the CBCL parent-report measures. This also indicates that the task is not optimal in this population, as the constructs measured by the CBCL have a well-established relationship with EFs (McNeilly, Peverill, Jung, & McLaughlin, 2021; Utendale, Hubert, Saint-Pierre, & Hastings, 2011; Vuontela et al., 2013). We did find that EFs performance in Jordanian children is related to paternal education as well as school location (governorate). While data from Western cohorts often identifies effects of maternal education (Amso, Haas, McShane, & Badre, 2014; Hackman et al., 2014; Hackman, Farah, & Meaney, 2010; Hackman, Gallop, Evans, & Farah, 2015; Lawson & Farah, 2017; Ursache, Noble, & Blair, 2015), our data are consistent with other cognitive development studies in Jordanian children. For example, a study of cognitive abilities and reasoning in Jordanian children between the ages of 5-to-9 years old found that reasoning skills improved with higher paternal occupation levels (Almomani, Al-Momani, Alsheyab, & Al Mhdawi, 2018). The same study showed that children living in urban areas had higher reasoning skills scores than those living in rural areas. A separate study of Jordanian children between the ages of 6 and 12 years old found that the factors that significantly contributed to children's cognitive functioning included location of residence (Almomani et al., 2014). In our data, the correlations between EFs scores, as measured by the H&F task, and CBCL scores (Table 5) and other sociodemographic factors were no longer statistically reliable when statistical models included School Location and Paternal Education variables in the models (Tables 6–8). In the broader context, these findings are consistent with literature reviewed in the lived experience section indicating that (a) inequities in Jordan are driven primarily by differences between governorates (Programme, 2015) and (b) the involvement of fathers with higher education levels in their own children's education is a prominent cultural feature impacting children's experiences and outcomes (Ridge & Jeon, 2020).

In sum, while the H&F task is used in many studies (Table 1), the majority are with children living in Western countries. Here we asked whether such a task can be used in non-Western communities by testing it in Jordanian children. We specifically asked whether the task was sensitive enough to pick up on differences in the three task conditions (working memory, inhibitory control, cognitive flexibility), was sensitive to developmental change in EFs in this population, and showed individual differences and variability by sociodemographic variables. We also asked whether the task was sensitive enough to pick up on associations between EFs in non-Western communities and parent-report of related constructs as measured by CBCL externalizing, internalizing, and academic performance scales.

Table 2. Descriptive statistics for demographics information including age by group, maternal education, paternal education, and family income.

	M	*SD*	Range (min, max)
Age in years	7.02	0.81	(5.4,8.8)
5.5–6.5-year-olds ($N = 33$)	6.16	0.32	(5.4,6.7)
6.5–7.5-year-olds ($N = 35$)	7.1	0.25	(6.7,7.5)
7.5–8.5-year-olds ($N = 25$)	8.05	0.35	(7.6,8.8)
Maternal Education (Years)	14.67	2.76	(0,20)
Paternal Education (Years)	14.13	2.48	(1,20)
Family Income (JD)	9980.51	8287.94	–36,000

Table 3. Descriptive statistics for H&F accuracy by age group.

	Congruent		Incongruent		Mixed	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age in years						
5.5–6.5-year-olds ($N = 33$)	.89	.13	.73	.25	.60	.16
6.5–7.5-year-olds ($N = 35$)	.93	.10	.74	.21	.51	.15
7.5–8.5-year-olds ($N = 25$)	.91	.08	.72	.17	.59	.15
Total	.91	.11	.73	.21	.55	.15

Table 4. Descriptive statistics for H&F reaction time by age group.

	Congruent		Incongruent		Mixed	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age in years						
5.5–6.5-year-olds ($N = 33$)	756.30	223.27	856.72	252.02	996.21	178.23
6.5–7.5-year-olds ($N = 35$)	695.51	198.49	843.57	202.00	995.16	163.65
7.5–8.5-year-olds ($N = 25$)	652.60	217.16	815.82	193.85	964.15	129.11
Total	705.54	214.30	840.78	218.59	987.20	159.67

Table 5. Correlation table for variables of interest including measures of socioeconomic status, and CBCL correlations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Family Income													
(2) Maternal Education	.28**												
(3) Paternal Education	.44**	.40**											
(4) H&F: Congruent Accuracy	.18	.07	.17										
(5) H&F: Incongruent Accuracy	.22*	−.07	.19	.46**									
(6) H&F: Mixed Accuracy	.30**	.18	.22*	.41**	.53**								
(7) H&F: Congruent RT	−.1	.01	−.19	−.16	−.34**	−.36**							
(8) H&F: Incongruent RT	−.12	.01	−.10	−.02	−.16	−.37**	.72**						
(9) H&F: Mixed RT	.22*	.05	.08	.12	.12	.07	.50**	.58**					
(10) Externalizing Behaviors	.01	−.10	−.07	−.25*	−.20	−.21*	.11	−.15	−.40				
(11) Internalizing Behaviors	.06	−.18	−.13	−.19	−.25*	−.16	.04	−.08	−.01	.40**			
(12) School Competency	.07	.18	.25*	.25*	.25*	.21*	−.30**	−.13	−.08	−.14	−.12		
(13) Age in Years	.07	.00	−.13	.09	−.01	.07	−.17	−.12	−.12	−.08	−.06	.03	
(14) Go/NoGo Accuracy	.29**	.05	.02	.31**	.20	.36**	−.22*	−.19	.09	−.19	.10	.06	.32**

Note: *$p < 0.05$, ** $p < 0.01$.

Table 6. Univariate analysis predicting school competency score.

Predictor	*SS*	*df*	*MS*	*F*	*p*
Intercept	660.56	1	660.56	24.70	<0.001
School Location	12.41	1	12.41	.46	0.50
Internalizing Behaviors	4.47	1	4.47	.17	0.68
H&F: Congruent Accuracy	3.6	1	3.6	.14	0.72
H&F: Incongruent Accuracy	39.14	1	39.14	1.46	0.23
H&F: Mixed Accuracy	5.34	1	5.34	.20	0.66
Externalizing Behaviors	33.44	1	33.44	1.25	0.27
Maternal Education	29.14	1	29.14	1.10	0.30
Paternal Education	144.50	1	144.50	5.40	0.02
Error	2192.98	82	26.74		

Table 7. Univariate analysis predicting externalizing score.

Predictor	*SS*	*df*	*MS*	*F*	*p*
Intercept	1181.68	1	1181.68	4.59	<0.001
School Location	1.86	1	1.86	21.24	0.86
Internalizing Behaviors	815.25	1	815.25	.03	<0.001
H&F: Congruent Accuracy	155.87	1	155.87	14.65	0.10
H&F: Incongruent Accuracy	25.82	1	25.82	2.80	0.50
H&F: Mixed Accuracy	27.78	1	27.78	.46	0.48
School Competency	58.15	1	58.15	.50	0.31
Error	4674.48	84	55.65	1.05	

Table 8. Univariate analysis predicting internalizing score.

Predictor	*SS*	*df*	*MS*	*F*	*p*
Intercept	795.27	1	795.27	12.67	<0.001
School Location	10.87	1	10.87	.17	0.68
H&F: Congruent Accuracy	31.37	1	31.37	.50	0.48
H&F: Incongruent Accuracy	153.16	1	153.16	2.44	0.12
H&F: Mixed Accuracy	3.40	1	3.40	.05	0.82
Externalizing Behaviors	895.45	1	895.45	14.27	<0.001
Maternal Education	106.01	1	106.01	1.69	0.20
Paternal Education	97.08	1	97.08	1.55	0.68
School Competency	10.48	1	10.48	.17	
Error	5145.87	82	62.75		

Overall, the results were mixed. The task had some sensitivity to individual variability in sociodemographic variables but not to expected changes in age-related performance. Moreover, task performance bore no clear relationship to individual differences in parent report of related constructs as measured by the CBCL.

Null results are difficult to interpret. As such, we can conclude only that this task does not seem to be appropriate for assessing *developmental change* in EFs from early to middle childhood in this non-Western group of children. The task may be beneficial for investigations that consider only condition-level effects, but it does not seem to us to be sufficiently sensitive to detect developmental change across our age range in this Jordanian sample. We have no reason to suspect that our sample is not representative of the greater Amman area. As we note in the General Country and Demographic Data section, our sample data were consistent with previous data on family characteristics as well as representative of basic demographic measures. It is notable that there is a correlation between the H&F Mixed Condition and Go/NoGo task performance (Table 5). Taken together with the observed H&F condition-level effects (see Figure 2), it seems that the H&F task is indeed capable of indexing aspects of EF, but not developmental change in this cohort of children. To reiterate, the same group of children provided evidence of developmental change on a Go/NoGo task and the same country population provided evidence of EF development using a DCCS task (Al-Hmouz & Abu-Hamour, 2017). As such, it is unlikely that the failure of this task to detect developmental change reflects anything but task-based insensitivity.

The precise reasons for this insensitivity are not clear. It might be that the Mixed block, where one might expect the most improvement, proved too confusing or removed from everyday demands or experiences to children across the age range tested, and so performance in general was poor. It is entirely possible that with sufficient practice, i.e., if the task had multiple blocks of the Mixed condition, children would adapt to the task and perform differently. Future work can consider this possibility. However, that is not currently how this fairly common task (see Table 1) is used. Alternatively, or in addition, the Mixed block may have been demanding *and* lacked any motivation for effort investment in this population. The Face Go/NoGo task uses a social stimulus which may have been rewarding or at least engaging to children. Similarly, the DCCS involves interaction with another person who is handing you the cards to sort. It is possible that this H&F task lacked motivational elements or interest for effort investment.

Currently, of all the EFs assessments validation studies conducted in non-Western populations (and published in English), only 17.9% (10 papers) were done in Middle Eastern samples (Kusi-Mensah et al., 2018). Future work might consider taking the principles of EF tasks like H&F and adapting them to culturally appropriate testing contexts. An alternative to using Western tasks as they are to begin with qualitative assessments of EF-relevant lived experience of children in both home and school environments and then to use that information to develop tasks that test how EFs manifest in one's daily experience. For example, do children need to plan their own day? If so, at what ages? Do they have routines around bed and mealtimes? Are they expected to conduct chores in the home or help care for younger children? Alternatively, are they completely cared for by caregivers and asked only to focus on play and studies? Answers to such questions can support methods and design-based contextualization of EF measurement so that they might closely mirror demands for rule-guided behavior that are consistent with children's lived experiences, in order to maximize task utility and sensitivity.

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Data availability statement

Data not available due to ethical restrictions.

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