Are Time and Action Dissociated in Young Children’s Time Estimation?

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Experiment 1 examined whether there is a developmental shift in children’s ability to differentiate a given amount of time from a particular action. In three sessions, 3- and 5 1/2-year-olds were trained to produce an action (i.e., pressing on a squeezer) for 5 s. Twenty-four hours later, control participants were required to produce this target duration using the same action, whereas experimental participants had to do so with a new action (i.e., pressing a button). The results showed that the 5 1/2-year-olds achieved the same temporal performance in both groups. In contrast, the 3-year-olds’ temporal performance was significantly better in the control group than in the experimental group. Two additional studies were run with 3-year-olds, the first designed to assess the transfer without a delay, and the second with explicit instructions to transfer duration. In each study, 3-year-olds’ temporal performance was significantly better in the control group than in the experimental group. These findings as a whole suggest that 3-year-olds fail to understand that one and the same duration can be shared by several different actions. Early implicit knowledge of time was discussed.

Temporal order and duration are two fundamental temporal properties of events. In the field of developmental psychology, only knowledge about temporal order has been extensively studied in young children (Bauer & Herstsgaard, 1993; Bauer & Mandler, 1989, 1992; Bauer & Shore, 1987; Bauer & Travis, 1993; O’Connel & Gerard, 1985). The lack of studies on knowledge about duration is mainly due to the strong theoretical position of cognitivists who consider durat-
tion as a sophisticated product of the mind (Anderson, 1983; Ornstein, 1969). In Anderson’s (1983) temporal string model, duration is inferred from temporal order, which is the only temporal information stored in long-term memory.

Most developmentalists have provided data consistent with the cognitive standpoint (Pouthas, Droit, & Jacquet, 1993). They have shown that the ability to judge time emerges relatively late in ontogenesis, at about age 5 years. Furthermore, they agree that children infer duration from other information. Debate has centered, however, on the nature of this information. Piaget (1946), who worked on kinetic events, showed that time judgment depends upon the ability to coordinate movements with their speed. In a classical Piagetian task, children were shown two cars which started and stopped running together on parallel tracks, but the one running faster stopped further ahead. In this condition, up until the acquisition of concrete operations, children claim that the car stopping further ahead runs for a longer time. Based on their studies of temporal comparison tasks with static events, Levin (1992) and Montangero (1977, 1979, 1993) argued that duration was instead derived from the coordination between beginnings and endings of events (i.e., temporal order).

However, in these temporal comparison tasks, children’s difficulties in judging time may result from limited general cognitive abilities to coordinate several cues rather than from a specific problem of time estimation (Levin, 1979; Richie & Bickhard, 1988; Wilkening, Levin, & Druyan, 1981). Thus, in order to examine time estimation in younger children, psychologists have simply asked young children to produce or to reproduce a single duration (Crowder & Hohle, 1970; Droit-Volet, 1999a; Fraisse, 1948; Fraisse & Orsini, 1958; Macar, 1988; Matsuda & Matsuda, 1983; Montangero, 1977). However, in spite of this task simplification, children still fail to show accurate temporal judgment below the critical age of 5 years. Therefore, Fraisse (1982) concluded that a prerequisite for accurate time judgment is the acquisition, at about 5 years, of an explicit knowledge about time, where time is abstracted from events and allows to measure events whatever their characteristics.

More recently, psychologists have succeeded in observing temporal judgment abilities in 3-year-olds, who have not yet mastered the concept of homogeneous time. Friedman (1990) showed that 3-year-olds were successful in comparing the duration of daily activities by placing a marker on a judgment scale going from “a very short time” to a “very long time,” although their judgment lacked precision. More recently, Droit (1994, 1995) showed that 3-year-olds were able to accurately produce the target duration of an action when trained to do so.

Three-year-olds’ temporal ability seems to be specific to the duration of events or actions (filled duration). Their performance in estimating temporal intervals (empty duration) is far inferior. Indeed, Droit (1994) observed, with a conditioning technique, that 3-year-olds could learn to regulate a button-press duration, but not a temporal interval between two presses, as shown in previous studies (Bentall, Lowe, & Beasty, 1985; Droit, Pouthas, & Jacquet, 1990, 1991).
A Dissociation between Time and Action

In addition, 3-year-olds required personal experience with the critical duration through their action, guided either by a model to imitate (Droit, 1995) or by an external clock (Droit, 1994), where they were trained to produce the target duration in synchronization with the experimenters’ action or the lighting of bulbs, respectively. Without this kind of previous training, in a single session, their temporal performance remained poor, even with filled duration (Droit-Volet, 1999a; Matsuda, Miyazaki, & Matsuda, 1983).

On the basis of these empirical data, Droit (1995, 1998, 1999b) concluded that 3-year-olds possess implicit procedural time knowledge that radically differs from a mature concept of time. In others words, they know how to time their actions before they know that their actions take time. She proposed that children at this age possess a kind of action-specific time. More precisely, given that an action may be automatically encoded with its duration (Michon, 1990), young children should therefore be able to reactivate duration associated with an initial action on a retrieval task (e.g., time production on several sessions). This would explain 3-year-olds’ failure at traditional single time production tasks, in which they have no opportunity to remember or to experience a target duration through their action. Finally, in these tasks, explicit knowledge about duration would facilitate the processing of time by selectively orienting children’s attention to temporal information (Droit, 1997).

Although children’s performance improves in accordance with the temporal features of a situation until age 5, children remain effectively unable to articulate temporal rules governing their behavior (Bentall, Lowe, & Beasty, 1985; Droit, Pouthas, & Jacquet, 1990; Pouthas, Droit, Jacquet, & Wearden, 1990). In temporal learning, when successful 3-year-olds were asked how they got the positive feedback (i.e., laughing clown), which was contingent on action duration, they never gave temporal rules. They only said: “I must have the laughing clown” or “I have to win” (Droit, 1998). Recently, Droit-Volet (1998) showed that 3-year-olds produced more accurate response durations when they were instructed to press “hard enough” (i.e., force rule) rather than to press “long enough” (i.e., temporal rule). Moreover, when they were instructed to press “harder,” they pressed both harder and longer. In the same situation, older children aged 5 1/2-year-olds, only pressed harder. They never pressed longer. Thus, a force rule, not a time rule, seems to control time productions in young children. This estimation of time via a force rule in 3-year-olds reveals that time is still not dissociated from action (Arlin, 1986, 1989; Levin, 1992; Matsuda, 1991; Montangero, 1977). Consequently, a duration initially encoded with an action would not be assigned to a possible other action. It is only when children begin to differentiate time from action, at about age 5, that a duration learned with an action should be transferred to another action.

In the present study, the transfer paradigm was used to investigate the nature of 3-year-olds’ filled duration knowledge. The hypothesis was that with implicit time knowledge, 3-year-olds are able to remember a given duration acquired
throughout the practice of an action, but not, unlike 5 1/2-year-olds, to transfer this same duration to a new action. Three- and 5 1/2-year-old participants performed a response duration task over four sessions with a target duration of 5 s (+/− 1 s). During the first three sessions, they were trained to produce the target duration on a responding system (pressing a rubber squeezer) by imitating an experimenter (i.e., simultaneous imitation). In the last session, they were randomly assigned either to an experimental group, involving a different response system (pressing a button), or to a control group involving the same response system as that used during the training sessions. We expected that the 3-year-olds would produce more accurate response durations in the control condition than in the experimental condition, whereas the 5 1/2-year-olds would produce the same level of accurate response durations in the control condition as in the experimental condition. Accordingly, the 3-year-olds should produce shorter and more variable durations in the experimental group than in the control group, whereas no difference should emerge between the two groups of 5 1/2-year-olds.

**EXPERIMENT 1**

**Method**

**Participants.** The final sample consisted of 40 children: twenty 3-year-olds (10 girls and 10 boys, mean age = 3.3 years; $SD = 0.2$) and twenty 5 1/2-year-olds (10 girls and 10 boys, mean age = 5.6 years; $SD = 0.3$). They were recruited from the same nursery school in Clermont-Ferrand, France.

**Materials.** The child was seated at a table opposite a toy theater and next to the experimenter. Two response systems were used. The first response system was a red rubber squeezer, such as the one used in Macar’s (1988) study (diameter 5 cm). The child had to press the ball in his or her hand. The second response system was a red button mounted on a wooden box. The two response systems were connected to a microcomputer which stored each press duration and generated visual feedback. The visual feedback was the projection of a slide for 3 s on the toy theater’s screen. When the child produced an accurate response, the slide was a colored picture taken from a popular cartoon. When the child produced an inaccurate response, the slide was black. Slides were grouped in series defined by the type of cartoon: Snow White, The Lion King, Merlin, etc. The cartoon was different for each experimental session.

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¹ Six additional children (four 3-year-olds and two 5 1/2-year-olds) participated in the experiment, but they were not given the last transfer test because they did not produce a sufficient number of accurate responses after imitation training.
Procedure. The child’s task was to produce a target response duration of 5 s on six phases of 20 trials each distributed on four sessions, one per day as described in Table 1. When the child produced a response duration between 4 and 6 s, the feedback was a colored slide. When the response duration was less than 4 s or more than or equal to 6 s, the given feedback was the black slide. If the duration reached 10 s, the black slide was presented directly.

In the first three sessions, each participant received an imitation training phase with the same response system (i.e., a rubber squeezer; Table 1). In the imitation phase, the experimenter had her own rubber squeezer, similar to the child’s. At the beginning of the first session, she told the child to imitate her while saying, “Look, I’m going to teach you how to make cartoon pictures appear. Do exactly as I do.” For the first trial only, the experimenter pressed with her right hand on her own response squeezer during 5 s while pressing the child’s hand on his or her squeezer with her left hand. Then, she released simultaneously her own squeezer and her left hand on the child’s. The color slide appeared and the experimenter added, “We’ve made it, we’ve got a cartoon picture! If we hadn’t done it right, we would have got a black picture.” Finally she said, “Now, let’s try together to get a cartoon picture. Ready, let’s do exactly as I do.” Before each trial, the experimenter repeated, “Ready, let’s do exactly as I do” and made sure that the child synchronized his or her press with hers.

On session 1, immediately before the first imitation phase, the spontaneous response durations produced with the rubber squeezer were collected in a baseline phase. The experimenter introduced this pretraining phase by saying, “Take the squeezer in your hand, and play at making cartoon pictures appear.”

To evaluate the effect of imitation training on participants’ response durations, children were submitted to a retention test given immediately after the last imitation phase in session 3. The experimenter introduced this phase by saying, “Now, you try to make cartoon pictures appear all by yourself!” In this phase, the response system was still the rubber squeezer and the child was not given simultaneous imitation instructions. Four 3-year-olds and two 5 1/2-year-olds did not

Table 1. Experiment 1: The Response System (Squeezer or Button) Used in the Different Phases of 20 Trials of Each Experimental Session

<table>
<thead>
<tr>
<th>Session 1: day 1</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Phase</td>
<td>Squeezer</td>
<td>Squeezer</td>
</tr>
<tr>
<td>Imitation Phase</td>
<td>Squeezer</td>
<td>Squeezer</td>
</tr>
</tbody>
</table>

| Session 2: day 2 |
|-----------------|---------------|--------------------|
| Imitation Phase | Squeezer      | Squeezer           |

| Session 3: day 3 |
|-----------------|---------------|--------------------|
| Imitation Phase | Squeezer      | Squeezer           |
| Retention Phase | Squeezer      | Squeezer           |

| Session 4: day 4 |
|-----------------|---------------|--------------------|
| Transfer Test   | Squeezer      | Button             |
participate in the transfer test, because they did not learn the target response duration. Two criteria of learning were chosen on the basis of the oldest children’s performance on a similar temporal production task with imitation instructions (Droit, 1995): (a) 50% of response durations between 3 and 7 s of which at least 35% were between 4 and 6 s, and (b) a modal response distribution focused on the target duration (5 s). The six participants who did not meet these criteria were not included in the final sample.

The transfer test was administered in a fourth session. For this test, the 3- and the 5 1/2-year-olds were randomly assigned either to a control group or to an experimental group. In the control group, the child had the same squeezer as in the previous imitation sessions. In the experimental group, the child used the button. Nothing else was changed in the experimental situation, except that the experimenter did not have her own response system. In each group, the experimenter gave the same instructions at the beginning of the test, “Now, you try making cartoon pictures appear.” Like the imitation sessions, the test was composed of 20 trials.

Results

Training Analysis. For each experimental phase, the percentage of accurate responses (i.e., greater than or equal to 4 s and less than 6 s) out of the total number of responses (i.e., 20) was used as an index of temporal differentiation. Figure 1 presents the percentage of accurate responses obtained by the 3- and the 5 1/2-year-olds in the control and the experimental groups for the various phases of the experiment. To ensure that children had achieved an equal level of performance in the different groups after the training sessions with simultaneous imitation, an Age × Group × Sex analysis of variance (ANOVA) was run on the percentage of accurate responses (using arcsin transformed data) in the immediate retention phase. There were no main effects of sex, $F(1, 32) = 0.12, p > .05$, age, $F(1, 32) = 2.14, p > .05$, or group, $F(1, 32) = 1.12, p > .05$. The Age × Group interaction was not significant, $F(1, 32) = 0.07, p > .05$.

Similar 3-way ANOVAs were computed on (a) the mean response duration and (b) the coefficient of variation, in the immediate retention phase. These analyses revealed neither significant main effects nor significant interactions.

The global pattern of results confirms that the 3- and the 5 1/2-year-olds did not reach different levels of performance in the control and the experimental groups through the training with simultaneous imitation.

Transfer Analysis. Accurate responses. A within-subject factor was introduced to assess learning effects across the transfer test (Figure 2). The 20 trials

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2 In Experiments 1, 2, and 3, for each statistical analysis, the percentages of accurate responses were subjected to an arcsin transformation. However, Figures report the raw percentages.

3 To assess variability in time production, a coefficient of variation was calculated by dividing the standard deviation by the mean duration.
Figure 1. Experiment 1: Percentage of accurate responses for 3- and 5 1/2-year-olds in the control and the experimental groups as a function of the different experimental phases: (a) baseline, (b) immediate retention, (c) transfer test.
were grouped into four blocks of five trials. An ANOVA was performed on the percentage of accurate responses with 3 between-subject factors (Sex, Age, Group) and 1 within-subject factor (Block).

No main effect of sex was observed, $F(1, 32) = 0.76, p > .05$. The main effects of age, $F(1, 32) = 43.36, p < .05$, group, $F(1, 32) = 4.83, p < .05$, and block, $F(3, 96) = 5.67, p < .05$, reached significance. The ANOVA also revealed significant interactions between age and group, $F(1, 32) = 9.92, p < .05$, and group and block, $F(3, 32) = 4.01, p < .05$. The interaction between age and block was not significant. However, an Age $\times$ Group $\times$ Block interaction emerged, $F(3, 32) = 4.70, p < .05$.

A Tukey post-hoc test showed that in each block of trials the 3-year-olds produced fewer correct responses in the experimental group than in the control group ($p < .05$). However the experimental participants’ accurate responses were higher in the transfer test than in the baseline, as indicated by a Wilcoxon matched-pairs sign ranks test (8.5% vs. 1.5%; $Z = -2.03, p < .05$). In contrast,

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4 Because the assumption of homogeneity of variance was not met for the baseline phase due to the high number of participants who did not obtain accurate responses in the baseline phase, a nonparametric statistic analysis was run (i.e., the Wilcoxon matched-pairs signed-ranks test).
for 5 1/2-year-olds, no difference emerged between the experimental group and the control group, except for trial block 4 in which the experimental participants produced more correct responses than the control participants (82% vs. 62%; \( p < .05 \)).

In addition, a Sheffé post-hoc test revealed that, in the control condition, the percentage of accurate responses was higher for 5 1/2-year-olds than for 3-year-olds (43% vs. 63%; \( p < .05 \)). In fact, for 5-year-olds, the percentage of accurate responses significantly increased between the immediate retention phase and the transfer test (t-test for paired samples, \( t(9) = -2.94, p < .05 \)). For 3-year-olds, the decrease of accurate responses between the immediate retention phase and the transfer test was not significant (t-test for paired samples, \( t(9) = 1.90, p > .05 \)).

**Mean response duration and its variability.** Age × Group × Sex × Block ANOVAs were computed on the mean response duration and its variability (Table 2).

The ANOVA performed on mean duration showed that the main effect of sex was not significant, \( F(1, 32) = 0.44, p > .05 \). The main effects of age, \( F(1, 32) = 1.84, p > .05 \), and block, \( F(3, 96) = 0.33, p > .05 \), were also not significant. Only a main effect of group appeared, \( F(1, 32) = 6.13, p < .05 \). However, age significantly interacted with group, \( F(1, 32) = 8.04, p < .05 \). There were no additional significant interactions.

Planned comparisons showed that the 5 1/2-year-olds produced no different mean durations in the experimental group than in the control group (5.12 s vs. 4.93 s), \( F(1, 16) = 0.41, p > .05 \). In contrast, the 3-year-olds produced shorter mean durations in the experimental group than in the control group (3.41 s vs. 6.20 s), \( F(1, 36) = 7.65, p < .05 \).

The statistical analysis of the coefficient of variation revealed a significant main effect of age, \( F(1, 32) = 16.78, p < .05 \). There were no main effects of sex, \( F(1, 32) = 0.22, p > .05 \), group, \( F(1, 32) = 0.49, p > .05 \), or block, \( F(1, 32) = 0.44, p > .05 \).

| Table 2. Experiment 1: Mean Durations (s) and Coefficients of Variation for 3- and 5 1/2-year-olds Across Trial Blocks in the Control Group and the Experimental Group |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                 | Control Group   | Experimental Group |                  |
|                                 | M. | Coef. | M. | Coef. |
| 3-year-olds                     |    |       |    |       |
| Block 1                         | 6.00 | .26 | 3.03 | .43 |
| Block 2                         | 6.31 | .32 | 3.40 | .35 |
| Block 3                         | 6.18 | .26 | 3.47 | .42 |
| Block 4                         | 6.30 | .28 | 3.74 | .34 |
| 5 1/2-year-olds                 |    |       |    |       |
| Block 1                         | 5.02 | .20 | 5.26 | .19 |
| Block 2                         | 4.75 | .22 | 5.36 | .00 |
| Block 3                         | 4.95 | .27 | 4.88 | .15 |
| Block 4                         | 5.02 | .21 | 4.98 | .11 |
1.15, \( p > .05 \). Age and Group interacted significantly, \( F(1, 32) = 5.55, p < .05 \), but no other significant interactions were found. Finally, planned comparisons indicated that the 3-year-olds were more temporally variable than the 5 1/2-year-olds in the experimental condition, \( F(1, 16) = 14.66, p < .05 \), but not in the control condition, \( F(1, 16) = 2.60, p > .05 \).

**Discussion**

As predicted, the 5 1/2-year-olds were able to transfer a target duration from one action to another. Indeed, their temporal performance (i.e., accurate responses, mean duration, coefficient of variation) was similar in the experimental condition and in the control condition. In contrast, the 3-year-olds failed to reproduce the target duration with a new action. They produced less accurate responses in the experimental group than in the control group. Furthermore, durations were shorter and more variable in the experimental group.

From the accurate transfer in the 5 1/2-year-old children, it can be inferred that 5 1/2-year-olds have abstracted the duration from the action learned by imitation and then assigned this duration to another action. These findings suggest that, at this age, children understand that the same duration can be shared by two different actions.

Unlike 5 1/2-year-olds, the 3-year-olds' failure to transfer suggests that duration is still not dissociated from its original action. However, in the present study, definitive conclusions cannot be drawn. Indeed, variables other than children’s understanding of time may have played a role preventing them from transferring duration. In the control condition, 3-year-olds were able to remember an action-specific duration after a delay of 24 hours between the retention phase and the transfer test. But in the experimental condition, the change of surface features (i.e., the use of a response button) may have interfered with the accessibility of the critical duration in memory. Thus, a second experiment was conducted to see whether the 3-year-olds’ failure to transfer persists without a delay of 24 hours between the immediate retention phase and the transfer test.

**Experiment 2**

Experiment 2 replicated Experiment 1, except that the transfer test occurred just following the immediate retention phase.

**Method**

**Participants.** A total of twenty 3-year-olds (7 girls and 13 boys, mean age = 3.02; \( SD = 0.30 \)), from the same nursery school in Clermont-Ferrand, participated in this experiment. No children who participated in Experiment 1 participated in this experiment. Four additional children were not retained in the final sample because they did not reach the training criterion defined above.
Material and Procedure. The apparatus was the same as that used in Experiment 1. The procedure was also identical, except for the temporal interval between the immediate retention phase and the transfer test. Thus, in this study, participants were given three successive experimental phases in session 3: (a) simultaneous imitation, (b) immediate retention, and (c) transfer test.

Results

Training Analysis. Figure 3 shows the percentage of accurate responses (i.e., responses between 4 and 6 s) in the control and the experimental groups as a function of the three experimental phases: (a) baseline, (b) immediate retention, and (c) transfer test. Group × Sex ANOVAs on the three dependent measures (percentage of accurate responses, mean duration and coefficient of variation) in the immediate retention phase revealed no significant effects (Accurate responses: Sex, F(1, 16) = 0.55, p > .05, Group, F(1, 16) = 1.93, p > .05; Mean duration: Sex, F(1, 16) = 0.08, p > .05, Group, F(1, 16) = 2.56, p > .05; Coefficient of variation: Sex, F(1, 16) = 0.08, p > .05, Group, F(1, 16) = 0.28, p > .05).

Transfer Analysis. Accurate responses. For the transfer test, an ANOVA was carried out on the percentage of accurate responses with 2 between-subject factors (Sex, Group) and 1 within-subject factor (Block; Figure 4). The analysis revealed main effects of group, F(1, 16) = 31.41, p < .05, block, F(3, 48) = 7.13, p < .05, and an Group × Block interaction, F(3, 48) = 6.34, p < .05. As indicated by a paired-samples t-test, the percentage of accurate responses in the

Figure 3. Experiment 2: Percentage of accurate responses for 3- and 5 1/2-year-olds in the control and the experimental groups as a function of the different experimental phases: (a) baseline, (b) immediate retention, (c) transfer test.
control group significantly decreased between block 1 and block 2 ($t(9) = 3.35, p < .05$). There was no main effect of sex.

*Mean response duration and its variability.* Table 3 shows the mean response duration and the coefficient of variation in the transfer test for the control and the experimental 3-year-olds as a function of trial blocks. An ANOVA was computed for each measure with sex and group as between-subject factor and block as within-subject factor. For the mean response duration, a main effect of group, $F(1, 16) = 114.32, p < .05$, and an interaction Group $\times$ Block, $F(1, 16) = 4.09, p < .05$, were found. No additional significant effects were observed. For the coefficient of variation, only a significant Group $\times$ Block interaction appeared, $F(3, 48) = 2.84, p < .05$.

**Discussion**

The results of Experiment 2 are consistent with those of Experiment 1. Indeed, 3-year-olds produced more accurate responses in the control group than in the experimental group. The response duration was also longer and less variable. However, in the present experiment, an interaction with the trial blocks emerged, resulting from a decrease in control participants’ performance in the second
block of trials in the transfer test. Session 3, composed of three successive phases of 20 trials, appeared to be too long for young children. However, this result does not throw into question the primary findings.

Thus, consistent with our predictions in Experiment 2 as in Experiment 1, the 3-year-olds did not succeed in transferring the critical duration acquired with an action to a new action. However, in both experiments, children were not explicitly instructed to perform this duration transfer. Thus, their failure may be due not to the implicit nature of their knowledge, but to a misunderstanding of the task demands. Until age 5, children are particularly dependent upon the support provided by the discourse of adults both in the understanding of a specific task and in the direction of their memory search (Bauer, 1997). A third experiment was therefore conducted to investigate whether the lack of duration transfer in 3-year-olds persists even with explicit instructions pointed out that the response duration required for the new response system (i.e., button) is the same as for the previous response system (i.e., squeezer).

**Experiment 3**

Experiment 2 was replicated in Experiment 3, except that 3-year-olds were now given temporal instructions, as described below.

**Method**

*Participants.* Twenty 3-year-olds (11 girls and 9 boys, mean age = 3.16; $SD = 0.32$) participated in the study. One child was not retained in the final sample because he did not reach the training criterion. All children were recruited from the same nursery school in Clermont-Ferrand. No children who participated in the previous experiments participated in this experiment.

*Apparatus and Procedure.* The apparatus was the same as that used in Experiments 1 and 2. The procedure used was also identical to that used in Experiment 2, except that participants received temporal instructions. Indeed, children were given explicit temporal instructions at the beginning of each experimental block.
phase. The additional temporal instructions were for: (a) the baseline phase: “. . . to make picture appear, you must press the button/the squeezer long enough;” (b) the copy-imitation phase: “. . . “do exactly as I do. We must press long enough on the button/squeezer;” (c) the immediate retention phase: “now try making the pictures appear all by yourself. Press long enough.” In addition, before the transfer test, the experimenter pointed out that the temporal task was the same than in the immediate retention phase. In the control group, she said, “Now, you try always making cartoon pictures appear, and to do so you must press always the same time,” and in the experimental group: “Now, we play with a button and not any more with a squeezer. But, the game is the same. You try always making cartoon pictures appear, and to do so you must press always the same time, the same time with the button than with the squeezer.”

Results

Training Analysis. As in the previous experiments, ANOVAs computed on data from the immediate retention phase revealed neither main effects of the manipulated variables nor any interactions (Figure 5) (Percentage of accurate responses (arcsin transformed): Group, $F(1, 16) = 0.09, p > .05$, Sex, $F(1, 16) = 0.001, p > .05$, Group × Sex, $F(1, 16) = 0.22, p > .05$; Mean duration: Group, $F(1, 16) = 1.72, p > .05$, Sex, $F(1, 16) = 2.41, p > .05$, Group × Sex, $F(1, 16) = 0.64, p > .05$; Coefficient of variation: Group, $F(1, 16) = 0.001, p > .05$, Sex, $F(1, 16) = 2.67, p > .05$, Group × Sex, $F(1, 16) = 1.37, p > .05$).

Transfer Analysis. Accurate responses. An ANOVA was run on the percentage of accurate responses (using arcsin transformed data) in the transfer test with Sex and Group as between-subject factors and Block as within-subject factor (Figure 6). Only a main effect of group, $F(1, 16) = 10.59, p < .05$, was observed. However, the Wilcoxon matched-pairs signed-ranks test indicated that the experimental participants produced more correct responses in the transfer test than in the baseline ($Z = 2.67, p < .05$).

To test the effect of temporal instructions, a combined ANOVA for Experiments 2 and 3 was conducted on the percentage of accurate responses with 3 between-subject factors (Experiment, Group, Sex) and 1 within-subject factor (Block). There was neither a main effect of experiment nor an Experiment × Group interaction, nor an Experiment × Group × Block interaction. However, experiment interacted significantly with block, $F(3, 96) = 3.37, p < .05$. The analysis showed main effects of group, $F(1, 32) = 44.62, p < .05$, and block, $F(3, 96) = 6.63, p < .05$, and Group × Block interaction, $F(3, 96) = 7.10, p < .05$.

Mean response duration and its variability. ANOVAs were conducted on mean response duration and the coefficient of variation with 2 between-subject factors (Group, Sex) and 1 within-subject factor (Block) design (Table 4). The ANOVA on mean response duration revealed neither main effects nor interactions.
Figure 5. Experiment 3: Percentage of accurate responses for 3- and 5 1/2-year-olds in the control and the experimental groups as a function of the different experimental phases: (a) baseline, (b) immediate retention, (c) transfer test.

Figure 6. Experiment 3: Percentage of accurate responses for 3- and 5 1/2-year-olds in the control and the experimental groups as a function of trial blocks in the transfer test.
For the coefficient of variation, only a main effect of group appeared, $F(1, 16) = 4.49$, $p < .05$, indicating that response durations were more variable in the experimental group than in the control group (.53 vs. .46).

For the transfer test, combined ANOVAs were run to compare Experiments 2 and 3 (i.e., with and without explicit temporal instructions), with experiment, group, and sex as between-subject factors, and block as within-subject factor. For mean response duration, the ANOVA showed no main effect of experiment. However, experiment interacted significantly with group, $F(1, 32) = 14.33$, $p < .05$, and subsumed a main effect of group, $F(1, 32) = 25.74$, $p < .05$. No additional significant effects were observed. A Sheffé post-hoc test indicated that experimental participants produced longer durations in Experiment 3 than in Experiment 2 (3.06 s vs. .60 s, $p < .05$). For the coefficient of variation, the statistical analysis revealed a significant Experiment × Group × Block interaction, $F(3, 96) = 3.14$, $p < .05$. In block 3, experimental participants’ temporal production was more variable with than without instructions (Tukey post-hoc test, $p < .05$). There were no other significant effects.

**Discussion**

In the present study, as in Experiments 1 and 2, the results showed that 3-year-olds obtained significantly more accurate responses in the control group than in the experimental group and their temporal productions were less variable. However, contrary to Experiments 1 and 2, 3-year-olds did not produce longer durations in the control group than in the experimental group. These findings suggest that 3-year-olds pressed longer with temporal instructions but they did not succeed in transferring a given duration from one action to another.

**General Discussion**

The findings from these three experiments were highly consistent. They showed that, without delay between the retention test and the transfer test (Experiment 2),
and with explicit instructions to transfer duration (Experiment 3), 3-year-olds’
temporal performance was always better in the control group than in the experi-
mental group: these children produced more accurate responses, and their tempo-
ral productions were less variable. In contrast, in Experiment 1, 5 1/2-year-olds’
temporal performance was similar in the control group and in the experimental
group.

In the transfer task, the objection could be made that 3-year-olds failed to ac-
cess the temporal rule set up during training. As Zelazo, Frye, and Rapus (1996)
have claimed, knowing the rules is not always enough to ensure their application.
In Zelazo et al.’s (1996) Cognitive Complexity and Control theory (CCC theory),
behavioral changes between 3 and 5 years of age are explained by the acquisition
of increasingly complex rule systems, where complexity corresponds to the num-
ber of embedded levels inherent in these systems. Three-year-olds still lack
higher-order rules allowing them to determine which dimension is relevant and
then to select which specific embedded rule to apply. However, as suggested by
Zelazo et al. (1996), 3-year-olds will consequently persist in applying the rules
that are strongly associated with the task. In fact, the salient common surface fea-
tures (i.e., experimenter, feedback, etc.) in the current experiments, and the struc-
tural similarity between the immediate retention phase and the transfer test,
should have enhanced children’s tendency to use the established temporal rule. In
addition, explicit instructions to transfer duration in Experiment 3 might be ex-
pected to help children access this rule. In spite of these different supports, how-
ever, the temporal transfer never occurred in 3-year-olds, suggesting that 3-year-
olds’ difficulty cannot be attributed to difficulty selecting an appropriate explicit rule.

It is nevertheless possible that a single change in surface features, (i.e., rubber
squeezer vs. button) totally disrupts the temporal transfer in young children. Chi,
Feltovich, and Glaser (1981) have shown that novice problem solvers in the do-
main of physics are often unaware of the structural features of problems and
hence treat superficially similar problems as if they were structurally similar.
Young children are also known to be particularly sensitive to contextual changes
(Nelson, 1986). A new response system perhaps changed the representation of
the task demands among the present participants. But, here again, the temporal
instructions should have prevented their failure to understand the task demand. In
addition, the relearning of the target duration in the transfer test should have been
facilitated. But, in Experiment 1, the results indicated no effect of trial block. An
effect of block appeared in Experiments 2 and 3, but it resulted from a decrease
in performance after several trial blocks. Most likely this indicates that the
3-year-olds were tired. Thus, in the end, the results as a whole suggest that the
3-year-olds failed to transfer the duration from action to another, because they
did not understand that one and the same duration can be shared by several actions.

Consistent with the present approach, these studies document differences in
knowledge about duration for 3- and 5 1/2-year-olds. At age 5 years, the concept
of time has arguably been raised to the status of a homogeneous time abstracted
from events, that can serve to measure two different actions, whatever their characteristics. A single duration can therefore be transferred from an action to another. At this age, time knowledge has reached a sufficient level of abstraction to be applied in a wide variety of actions or situations, even in those where they have not experienced the duration, as shown by their success in most temporal estimation tasks (Droit-Volet, 1999b).

Although 3-year-olds apparently did not possess explicit knowledge of duration, they were nevertheless capable of remembering the duration of a specific action after the synchronization training, that is, in a retention test occurring immediately (Experiments 2, 3) or 24 hours (Experiment 1) later. These findings suggest that they constructed implicit procedural knowledge about the duration of an action experienced during training. In contrast with explicit knowledge about homogeneous time developed somewhat later, Droit (1995, 1998) and Droit-Volet (1998, 1999b) proposed that 3-year-olds represent a kind of broken-time specific to each action or event, that requires no conscious awareness of temporal properties of action. Therefore, through practice, the duration would be automatically encoded with its original action and remain associated with it. That would explain why 3-year-olds were unable to attribute a given duration acquired with an action to another action. As suggested by Logan (1988), one of the main properties of automaticity is that it is specific to the stimulus and situation experienced during training, and typically transfer to new stimuli is very poor.

This idea of an early implicit knowledge of duration encourages a reconsideration of the attention models of adult time estimation (Thomas & Weaver, 1975; Zakay, 1989). According to these models, duration is encoded only if attention resources are allocated to temporal information. In retrospective time estimation, participants are informed that they have to judge the duration of a task when it is finished. In this condition, with lack of attention, the duration is supposedly not encoded. Temporal judgment is therefore reconstructed from information that remains in memory, that is, non-temporal information (Zakay & Block, 1996, 1998). For Poynter or Zakay, subjective duration is biased by the amount of segments within an event (Poynter, 1983; Zakay, Tsal, Moses, & Shahar, 1994). Recently, Boltz, Kupperman, and Dunne (1998) showed that, even in retrospective duration, time judgments become more accurate with experience: the more a melody is familiar, the more accurate is its retrospective estimate. This provides evidence that people can estimate duration without intending to. Thus, there is an incidental learning of duration experienced throughout an action during training. In this theoretical framework, without intending to do so, young children would be able to accurately estimate duration of actions that they have experienced. And their failure in traditional time estimation tasks would result from the fact that the estimates concerned an event that they have not personally experienced and encoded (implicitly) in memory.

In the developmental psychology of time, memory for duration per se has
been as a whole neglected. However, the present study indicates that after one day of retention, the 5 1/2-year-old control participants produced more accurate responses than the 3-year-old controls in the transfer test. Some researchers have studied how response delay between perceived duration and its judgment affects the memory of time (Hawkes, Warshan, & Ray, 1973; Zakay & Fallach, 1984). They showed that the longer the response delay, the greater the difference between objective and subjective duration. Finally, the memory traces about duration could be stronger in 5 1/2-year-olds than in 3-year-olds. Thus, it is possible that explicit knowledge of time influences memory of time. Consistent with Seymour’s (1980) theory, an additional explicit semantic code, such as “long time” or “short time,” could be associated to the temporal label of actions or events.

One question that should be raised here is whether explicit time knowledge derives from earlier implicit time knowledge. In a Piagetian approach, Karmiloff-Smith (1992, 1994) outlined a process of re-description of implicit knowledge into an explicit format. Volet (1998) showed that 3-year-olds produced more accurate response duration with force instructions than with temporal instructions, whereas the opposite was observed in 5-year-olds. According to Droit-Volet (1998), these findings reflect the first stage of the long process of time conceptualization. Indeed, the idea of time would derive from an early procedural knowledge by way of a feeling of effort. As she wrote, “children’s feeling that something is resisting them through their action may be the first step toward the understanding of duration” (p. 247).

However, Karmiloff-Smith (1992, 1994) asserted that this re-description of knowledge occurs at different ages depending on children’s experience in the domain of knowledge considered. But, in the time knowledge domain, this re-description occurs in an age range where cognitive shifts have often been put forward in other knowledge domains (Mounoud, 1994; Siegler, 1978; Piaget, 1974a, 1974b; Zelazo et al. 1996). Between 3 and 5 years, Piaget (1974a, 1974b) described the passage from a sensori-motor success stage to an understanding stage associated to the awareness of properties of actions. Siegler (1978) reported that 3-year-olds seem to proceed in an intuitive manner whereas 5-year-olds adopt analytic systematic strategies. From another perspective, Zelazo et al. (1996) evoked at these ages the growth of a higher-order rule system. Taken together, these findings seem to indicate a general cognitive development of representational flexibility between 3- and 5-year-olds, that allows children to resist interference from prepotent responses tendencies (Dempster & Brainerd, 1995).

Although it is difficult here to dissociate what was specific to time knowledge and general to cognitive development, the original procedure of temporal transfer, used in the present study, provided results that support our assumption about an implicit filled-duration knowledge in 3-year-olds, that differs from the later explicit knowledge of time. The problem is now to clarify the relation between these two kinds of knowledge.
REFERENCES


