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10.1002/dev.22169

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https://doi.org/10.1002/dev.22169

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Do infants avoid a traversable slope leading into deep water?

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ACKNOWLEDGMENTS | The authors would like to express their gratitude to the mothers and children who participated in the study. We also thank the University of Otago for providing the laboratory facilities, Nigel Barret for the technical support, and Joana Pereira for assistance in data coding. Rita Cordovil was supported by the Fundação para a Ciência e Tecnologia, under Grant UIDB/00447/2020 to CIPER - Centro Interdisciplinar para o Estudo da Performance Humana (unit 447).

Conflict of interest statement | The authors declare that there are no conflicts of interest.

ABSTRACT

Ramps used to access swimming pools are designed with a shallow slope that affords an easy access for all, including infants. Locomotor experience has been linked to infants’ avoidance of falling into the water from drop-offs, however, the effect of such experience on infants’ behaviour when a slope is offered to access the water has not been addressed. Forty-three crawling infants (M_{age} = 10.63 months, SD = 1.91; M_{crawling}}
= 2.38 months, SD = 1.77), and 34 walking infants ($M_{\text{age}} = 14.90, \text{SD} = 2.18$ months; $M_{\text{walking}} = 2.59$ months, SD = 1.56) were tested on a new Water Slope paradigm, a sloped surface (10°) leading to deep water. No association between infants’ avoidance of submersion and locomotor experience was found. Comparison with the results of infants’ behaviour on the Water Cliff (Burnay et al., 2020) revealed a greater proportion of infants reached the submersion point on the Water Slope than fell into the Water Cliff. Collectively, these results indicate a high degree of specificity in what locomotor experience teaches infants about risky situations. Importantly, sloped access to deep water appears to increase the risk of infants moving into the water thereby making them more vulnerable to drowning.

**Keywords:** water slope; water cliff; locomotor experience; perceptual-motor development; drowning.

**INTRODUCTION**

Drowning is a complex phenomenon and children between one and four years of age are especially vulnerable as they become mobile but incapable of recognizing the risk posed by bodies of water (WHO, 2014). Drowning and falls were recognised as the second and fourth, respectively, causes of unintentional deaths among children worldwide (Peden et al., 2009) and in many cases drowning is preceded by a fall. In Australia, for instance, most fatal drowning incidents in under 5-year-old children occur due to falls into the water (Royal Life Saving Society-Australia, 2016).

Redesigning pool fences and grilles on drain gates to prevent hair entrapment are some of the measures suggested to prevent drowning of young children (WHO, 2006).
However, little research attention has been directed towards the design of accessways to the water. The most common accessways to swimming pools are drop-offs leading to the water but ramps with a shallow slope that afford locomotion for all users are becoming more popular. Sloped entrances to swimming pools have been recommended to provide easier access to users with motor disabilities. For instance, the U.S. Department of Justice, under the Americans with Disabilities Act (ADA), issued regulations requiring that “pools [...] provide at least one accessible means of entry/exit, which must be either a fixed pool lift or a sloped entry” (U.S. Department of Justice, 2010). “Beach entry pools”, or zero entry pools, are becoming popular due to their attractive, universal design ensuring people with a wide range of motor abilities can access and enjoy public swimming pools. Zero entry pools feature a long, gentle slope from dryland into the water.

According to J. J. Gibson (1979, p. 127) “affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill” and this includes aquatic environments. The impact of sloped accessways to pools on infants’ perception and avoidance behaviour and risk for drowning incidents is not known. However, infants’ avoidance of bodies of water around sudden water drop-offs and infants’ avoidance of dryland drop-offs and slopes that pose varying degrees of risk have been investigated.

Infants’ adaptive behaviour on dryland slopes has been associated with self-produced locomotor experience. When tested longitudinally on increasingly steep slopes ranging from 4° to 36°, novice crawling and walking infants failed to avoid slopes beyond the slope boundaries they could successfully negotiate, but when tested as experienced crawlers and walkers, infants’ motor decisions became more accurate (Adolph, 1997).
Adolph (1997) used a psychophysical process to identify uphill and downhill slope boundaries for infants in each session. She described downhill slope boundaries as the steepest slope infants could descend using their last acquired method of locomotion (crawling for crawlers and walking for walkers). On average, the slope boundaries increased as infants accumulated self-produced locomotor experience, although a temporary decrease in the boundaries was observed during the transition from crawling to walking. Slope boundaries were also different between crawlers and walkers, with experienced crawlers showing steeper boundaries than new walkers (Adolph, 1997). Adolph et al. (2008) subsequently reported 20° as an average slope boundary for experienced crawlers and 12° for new walkers and Tamis-LeMonda et al. (2008) reported 24° for experienced walkers.

Other studies inspired by the classic Visual Cliff study of Gibson and Walk (1960) have shown that with an increase in locomotor experience infants are more likely to avoid crossing visual (Campos, Bertenthal, & Kermoian, 1992) and real cliffs (Kretch & Adolph, 2013). To investigate if the development of adaptive behaviour at the edge of a body of water was also associated with infants’ locomotor experience, Burnay and Cordovil (2016) created the Real Cliff / Water Cliff apparatus. The Real Cliff / Water Cliff apparatus consisted of a 2m-long and 75cm-high platform flanked on one side by a real drop-off and on the opposite side by a water cliff (i.e., water tub connected to the platform) and a harness system to ensure infants’ safety (see Burnay & Cordovil, 2016). Their first study showed that crawling infants avoided the real and the water cliff to a similar degree. On the real and the water cliff, the duration of crawling experience was a strong predictor of infants’ avoidance of falling, confirming the role of crawling experience in the development of adaptive behaviour around drop-offs (Burnay &
Surprisingly, a subsequent study showed that crawling experience, and not walking experience, was associated with walkers’ avoidance of falling on both cliffs (Burnay et al, 2020). The authors interpreted these results as evidence that through crawling experience infants learn how to adapt their behaviour to avoid falls (from heights and into the water), but when a new locomotor skill is acquired, infants’ need to recalibrate their perception of the environment and the amount of crawling experience facilitates the process. Although the Real Cliff / Water Cliff studies presented evidence that locomotor experience has an important effect on infants’ avoidance of falling into the water, it is not clear if the infants’ behaviour was influenced by the perception of water as a risky environment or if it was the perception of the risk of a fall motivating the infants’ adaptive behaviour.

**Present study**

The present study aimed to test the effect of locomotor experience on infants’ avoidance of submersion when a slope is offered to access the water and to determine whether infants’ avoidance of water cliffs in previous work (i.e., Burnay & Cordovil, 2016; Burnay et al, 2020) was based primarily on their avoidance of surfaces that do not afford safe locomotion or on their perception of bodies of water as risky environments. We tested crawling and walking infants’ behaviour on a new “Water Slope” paradigm - a gradual slope leading to deep water. If locomotor experience teaches infants to perceive water as an environment to avoid, locomotor experience should be linked to infants’ avoidance of submersion (i.e., water touching chin) on the Water Slope just as it was linked to the avoidance of falling into the water on the Water Cliff. In addition, we compared infants’ tendency to avoid submersion on the Water Slope to their tendency in previous studies to avoid falling into the water on the Water
Cliff. If infants avoid falling into the water on the Water Cliff because they perceived the water as dangerous, they would likewise avoid going into deep water on the Water Slope.

**METHODS**

**Participants** | Seventy-seven infants, 43 crawlers (25 boys and 18 girls) and 34 walkers (22 boys and 12 girls) were recruited from day-care centres, public swimming pools and referrals from parents. The walking infants were older and had more crawling, cruising and total self-produced locomotor experiences than crawling infants (see Table 1). Six additional infants, two crawlers and four walkers, were excluded due to compulsive crying or fussiness before or within the first 60 s of testing. The Human Ethical Research Committee of the participating institution approved this study (Ref 19/007). Parents were asked to provide informed consent before testing began.

**TABLE 1** | Crawling (N = 43) and walking (N = 34) infants’ descriptive values and differences in age and locomotor experiences.
INFANTS’ AVOIDANCE OF WATER SLOPES

| Experience                     | Walkers | Crawlers | Total   |  |  |  |  |
|--------------------------------|---------|----------|---------|  |  |  |  |
| Walkers                        | 2.61    | 0.00     | 1.79    | 5.09| 6.18|  |  |
| Crawlers                       | 0.00    | 0.00     | 0.00    | 0.00| 0.00|  |  |
| Total                          | 2.59    | 0.00     | 1.14    | 5.88| 5.68|  |  |
| Crawlers                       | 3.20    | 0.00     | 3.00    | 9.36| 9.70| <.001|  |
| Walkers                        | 7.57    | 0.00     | 7.57    | 12.88| 12.88|  |  |
| Total                          | 5.13    | 0.00     | 5.13    | 12.88| 12.88|  |  |

**Water Slope apparatus** | The Water Slope apparatus consisted of a horizontal starting platform attached to a 10° inclined ramp installed in a swimming flume (10x2.5x1.5 m) (see Figure 1). The 1m-long starting platform was above the water level and the 5m-long ramp began out of the water (5 cm above water level), leading to a water depth of 75 cm (below the mothers’ feet). The 10° slope was chosen because it is smaller than the average boundary slope for most infants (Adolph, 1997; Adolph et al., 2008; Tamis-LeMonda et al., 2008), ensuring, if on dry land, safe locomotion. For new walkers, 10° may challenge walking (Adolph, 1997) but infants were free to use any locomotor solution to move on the slope.

**FIGURE 1** | Water Slope apparatus illustration with measures.
The Water Slope apparatus was designed to be as similar as possible to the Real Cliff / Water Cliff apparatus (Burnay & Cordovil, 2016; Burnay et al., 2020). The entire apparatus (starting platform and ramp) was coated with a black and white checkerboard pattern and surrounded by 20 cm high side protections (from the starting platform and extending to the end of the ramp). A 10 m safety track and pulley system with an attached harness were installed in the ceiling above the apparatus. The pulley could move the entire length of the track, following the infants’ movements without constraining them. A rope (tether) passing through the pulley was tied to the infants’ custom-sized harness and was held at its other end by the experimenter responsible for the infants’ safety. During the tests, mothers sat on a platform installed 4.8 m away from the infants’ starting position and 37 cm above the water level, with their feet touching the water.

Procedure | Before visiting the laboratory, information about the study was sent to the mothers, who were asked to consult their baby books, photos and films to facilitate recall of the different onset-dates of their infants’ locomotor achievements.

After reporting their infants’ locomotor onset-dates in a structured interview and signing an informed consent form, mothers helped the experimenter to put the harness on their infants and attach the harness to a safety rope. To familiarize infants with general characteristics of the setting, mothers first sat with their infants on the starting platform, playing with them until they were calm and comfortable. Then, mothers moved to the opposite side of the flume and sat on the platform facing the infants. Next, the experimenter placed the infants in a quadrupedal posture (in the case of crawlers) or in an upright posture (in the case of walkers) on the starting platform (1 m away from the ramp) and initiated the trial. Mothers were instructed to touch and move the water
with their feet and to encourage their infants to get to them by showing them a toy and using positive verbal and gestural language (see Figure 2). As in the Real Cliff / Water Cliff paradigm, infants were tested wearing their normal daily clothes, except shoes. The ambient temperature was approximately 23°C and water temperature was approximately 28°C.

Infants had the opportunity to freely explore the apparatus while their mothers were calling for them. They could move around, sit, belly-crawl, crawl, cruise (supported by the lateral protections), walk, or engage in any other exploratory behaviours. To first touch the water, infants had to cross the 1.3 m distance from the starting platform to the water's edge. Some infants moved straight to the ramp, but others took their time exploring the starting platform or even bending over the side protections to touch the water surrounding the apparatus. After touching the water accessible by the ramp, infants chose whether or not to wade into the water. Some infants just stood nearby the water playing, some ventured straight into the water and some showed avoidance behaviours, such as shaking the head as a “no” sign or retreating to the starting platform. Infants who crossed the water line on the ramp (i.e., line separating the dry from the wet part of the ramp), were free to decide whether to move to the submersion point (i.e., water touching their chin), stay in the shallow water playing or retreat to the dry part of the apparatus. When the infants’ chin touched the water, the experimenter gently pulled them out of the water using the safety rope and harness mechanism and transported them to their mothers’ lap. The only situations in which the experimenter modified the infants’ movements were in the rare cases when the infants bent over the lateral protections and the experimenter prevented them from falling into the surrounding water or if 60 s after the trial started the infants had not moved from the
initial position and the experimenter placed them next to the water line, ensuring that the babies touched the water.

**FIGURE 2** | Synchronised cameras views. a) Camera front view; b) Camera back view. Photo reproduced with the permission of the infant's mother.

Trials ended (a) after 180 s, if the infant moved from the starting position but never touched the water; (b) 150 s after the infant touched the water; (c) when the infant reached the submersion point; (d) when the infant started compulsively crying and could not be calmed down. If the infant started compulsively crying during the first 60s of the trial, the test was ended and the infant was excluded from all subsequent analyses. If the infant started crying 60 s or more after the start of the trial and could not be calmed
down, the test was ended, and the infant was coded as avoider. Trials were filmed by 2 cameras (GoPro Hero 5) for subsequent data analysis (see Figure 2).

**Data coding** | Infants’ locomotor onset-dates were used to determine the following variables: (a) belly-crawling experience - since the day the infant moved alternating continuous hands-and-knees movements, for at least 5 cycles, with the belly touching the ground, until the onset-day of crawling; (b) crawling experience (i.e., hands-and-knees crawling) - since the day the infant moved with alternating continuous hands-and-knees movements, for at least 5 cycles, without the belly touching the ground, until the trial day (for crawlers) or until the onset of independent walking (for walkers); (c) cruising experience - since the day the infant walked supported by furniture for at least 10 consecutive steps, until the trial day (for crawlers) or until the onset of independent walking (for walkers); (d) walking experience – since the day the infant walked without any external support for at least 10 consecutive steps, until the trial day; (e) total self-produced locomotor experience – since the day the infants first self-locomoted (by belly-crawling, crawling, cruising or walking) until the trial day (see Table 1). The 5 cycles criterion for belly-crawling and crawling and 10 steps criterion for cruising and walking was the same as used by Burnay and Cordovil (2016) and Burnay et al. (2020).

Video data were coded for: *Avoidance behaviour*: infants who avoided the submersion point were coded as ‘avoiders’ and those who reached the submersion point were coded as ‘non-avoiders’; *Approaching time* (in seconds): from the moment the experimenter released the infants until the moment the infants touched the water with any part of their body. Infants who did not move from the starting position during the first 60 s of the trial were placed by the experimenter next to the water line with hands (in the case of crawlers) or feet (in the case of walkers) touching the water; *Retreat*
infants' avoidance of water slopes

Behaviour (yes/no): Infants were coded asretreating when i) after touching the waterthey moved away from the water, placing the whole body on the dry platform at leastonce, and when ii) after crossing the water line they moved away from the wet part ofthe apparatus to the dry part at least once; Distress (never; before touching the water;after touching the water; when in the water; right before reaching submersion point): ifthe infants showed any signs of distress (e.g., fussiness, crying) during the trial, but couldbe calmed down, the testing proceeded.

Results

Two coders scored 25% of the data (11 crawlers and nine walkers) to assess inter-raterreliability through intraclass correlation and kappa scores. Inter-rater reliability wasexcellent for approaching time (ICC = 0.999, 95% CI = 0.999–1.000). Inter-observeragreement was perfect (k = 1.00) for avoidance and retreat behaviours and strong (k =.886) for distress. Preliminary analysis showed no effect of sex on infants' behaviour sothe variable was collapsed for subsequent analysis.

Crawlers

Two crawling infants started crying after 60 s of testing. These tests were interrupted(at 65 s of testing for one infant and 100 s for the other) and the infants were coded asavoiders.

Avoidance behaviour | Of the 43 crawlers tested, 25 (58%) reached the submersion point and 18 (42%) avoided. Of the crawling avoiders, ten avoided getting into the water and
eight crossed the water line but avoided the submersion point. Of the crawlers that reached the submersion point, 11 showed no signs of perceiving the risk and just crawled down the slope, seven took their time exploring the setup and adopting cautious behaviours but ended up reaching the submersion point and seven reached the submersion point by falling in the water (three while adopting a crawling posture, three while cruising and one fell forward while sitting facing down the ramp). A series of logistic regressions was performed to analyse the probability of crawlers avoiding the submersion based on age or any of the locomotor experiences and all were statistically not significant (all $p > .381$) (see Figure 3).

**FIGURE 3** | Age and specific locomotor experiences (in months) for avoiding and non-avoiding infants on the water slope.

All models were statistically not significant revealing no evidence that crawlers’ avoidance of submersion can be predicted based on age or locomotor experiences.
INFANTS’ AVOIDANCE OF WATER SLOPES

Approaching time | Four crawlers (all avoiders) did not move from the initial position and had to be placed next to the water line by the experimenter and approaching time was coded as ‘missing’. No significant difference was found in the time avoiders (M = 64.3 s, SD = 51.3) and non-avoiders (M = 43.5 s, SD = 53.7) spent approaching the water. Spearman's rank-order correlations revealed a negative and moderate correlation between approaching time and crawling ($r_s = -0.45, p = .004$), cruising ($r_s = -0.39, p = .015$) and total self-produced locomotor ($r_s = -0.38, p = .018$) experiences. No correlation was found with age and belly-crawling experience.

Retreat behaviour | Twelve crawling infants (28%) (three non-avoiders and nine avoiders) retreated to the dry part of the apparatus after touching the water. Six of the nine avoiders that did not retreat after touching the water also never retreated from the wet part of the apparatus after crossing the water line, they entered the water, spent their time playing but, ultimately, avoided submersion. Only one of 32 crawlers that crossed the water line ever retreated back to the dry part of the apparatus after crossing the water line. This infant crossed the water line, retreated to the dry part of the apparatus after the water touched his chest then moved back into the water, reaching the submersion point. Statistically, avoiders (50%) moved away from the water more than non-avoiders (12%) after touching the water ($p = .006$, Pearson Chi-Square). However, there was no significant difference in crawlers’ retreat behaviour after crossing the water line between non-avoiders (only one) and avoiders (none). In none of the situations (i.e., retreating after touching the water or after crossing the water line) was crawlers’ retreat behaviour associated with age or locomotor experiences.

Distress | Only nine crawlers (21%) (four avoiders and five non-avoiders) showed signs of distress at some point during the test. Two of the avoiders could not be calmed down,
the test was interrupted before the maximum time of testing and they were coded as avoiders. Three crawlers (all non-avoiders) first showed signs of distress before touching the water, but, as soon as they touched the water, they became playful and relaxed and ended up reaching the submersion point. Three (all avoiders) started showing signs of distress after touching the water. These three crawlers never crossed the water line, suggesting that after touching the water they perceived that it would not afford going further. Two crawlers (one avoider and one non-avoider) showed signs of distress only after crossing the water line. Only one crawler started showing signs of distress right before the submersion point, when he perceived the water was too deep but it was too late to go back. Statistically, there was no difference in the number of avoiders and non-avoiders that showed signs of distress during the testing ($p = .860$, Pearson Chi-Square test).

**Walkers**

Two walkers started compulsively crying after 60 s of testing and could not be calmed down. The tests were interrupted (at 94 s for one and 63 s after touching the water for the other) and the infants were coded as avoiders. For one other walking avoider the test time after touching the water was less than 150 s because after exploring the setup she successfully climbed the back part of the apparatus, managing to bridge the gap between the apparatus and the deck (about 30cm-long), got to the flume’ deck and walked along the deck to her mother. Other infants explored this option, but this toddler was the only one who succeeded.
Avoidance behaviour | Twenty-three walkers (68%) reached the submersion point and eleven (32%) avoided. Of the avoiding walkers, only one avoided crossing the water line, the other ten crossed the water line but managed to avoid the submersion point. Most of the 23 non-avoiding walkers (14, 61%) reached the submersion point by falling into the water while adopting an upright posture; six of them fell when the water reached their chest, three when the water was on their belly button, four when the water was touching their knees and one fell when the water was touching her ankles. Three non-avoiders just walked straight to the submersion point without hesitation and six took their time exploring their options but ended up reaching the submersion point. Logistic regression revealed no association between age or locomotor experiences and the likelihood of walkers' avoidance of submersion (all \( p > .634 \)) (see Figure 3).

Approaching time | The approaching time of two walkers (one avoider and one non-avoider) was not coded due to technical error on the filming. No significant difference in the approaching time was found between walking avoiders (\( M = 40.8 \) s, \( SD = 60.5 \)) and non-avoiders (\( M = 29.6 \) s, \( SD = 42.0 \)). Spearman's rank-order correlations revealed a negative and moderate correlation between approaching time and belly-crawling experience (\( r_s = -0.37, p = .042 \)) and a positive and moderate correlation with crawling experience (\( r_s = 0.43, p = .014 \)). No correlation was found between age or any of the other locomotor experiences and walkers approaching time.

Retreat behaviour | Only three walkers (all avoiders) retreated to the dry part of the apparatus after touching the water. Five walkers (four avoiders and one non-avoider) retreated to the dry part of the apparatus at least once after crossing the water line. Of the four avoiding walkers who retreated after crossing the water line, one did so when the water was touching his ankles, two when the water was touching their knees and
one when the water was touching his chest while adopting a crawling posture. Statistically, avoiders retreated more (27%) than non-avoiders (0%) after touching the water ($p = .009$, Pearson Chi-Square) and avoiders retreated more (40%) than non-avoiders (4.3%) after crossing the water line ($p = .009$, Pearson Chi-Square).

Distress | Twenty of the walkers tested (59%), six (55%) avoiders and 14 (61%) non-avoiders never showed any signs of distress during the testing. Of the walkers who never showed signs of distress but reached the submersion point, nine fell into the water, three just walked to the submersion point and two approached the submersion point cautiously. Of the avoiders that never showed signs of distress during the testing, all crossed the water line. Of the five walkers who showed signs of distress and avoided the submersion point, one did so before touching the water (he crossed the water line and started compulsive crying after 63 s so the test was ended), one after touching the water and three after crossing the water line when the water was ankle deep. Of the nine walkers who showed signs of distress but ended up reaching the submersion point, one did so after touching the water, four after crossing the water line (two when the water was below their belly buttons and two when the water was touching their waists), and four only started showing signs of distress right before reaching the submersion point when the water was touching their necks. There was no association between the number of walkers showing signs of distress and their avoidance behaviour ($p = .726$, Pearson Chi-Square test).

### Crawlers vs Walkers’ avoidance behaviour on the Water Slope
Of the total 77 infants tested, 29 (38%) avoided the submersion point. Statistically, no significant differences in avoidance behaviour between crawlers (42% avoided) and walkers (32% avoided) was found ($p = .393$, Pearson Chi-square test). Logistic regression analyses revealed that neither age nor specific locomotor experiences were associated with all infants’ (crawlers and walkers together) avoidance of the submersion point.

**Water Cliff vs Water Slope**

Comparison between the current findings and those of Burnay et al. (2020) revealed a greater percentage of infants avoided falling on the Water Cliff than avoided reaching the submersion point on the Water Slope (see Figure 4).

**FIGURE 4** | Comparison between proportion of infants that avoided falling on the Water Cliff (Burnay et al., 2020) and infants that avoided the submersion on the Water Slope. ***$p < .01$, ***$p < .001$, Pearson Chi-squared tests.**
DISCUSSION

The main goal of the present study was to investigate if infants perceive a body of water as an unsafe environment that should be avoided and whether self-produced locomotor experience influences their behaviour. To that end, we examined crawling and walking infants’ avoidance of deep water when a gentle slope provided access to the water and compared the findings with those from previous studies in which infants had been exposed to an abrupt drop off into the water. The findings reveal new insights into the threats bodies of water pose to very young children who are mobile.

Contrarily to infants’ behaviour on the Water Cliff (Burnay et al., 2021), on the Water Slope, there was no association between infants’ avoidance of reaching the submersion point and self-produced locomotor experience. Importantly, the percentage of infants that avoided falling into the water on the Water Cliff was higher than the percentage of infants that avoided reaching the submersion point on the Water Slope.

Without water, the Water Cliff and the Water Slope apparatus would afford different possibilities for action and risks to infants. The Water Cliff would represent a real cliff and, as shown in the Real Cliff / Water Cliff studies (Burnay & Cordovil, 2016; Burnay et al., 2020), would result in a sudden fall if infants crawled or walked over the edge. In the absence of water, the 10° slope would afford a safe crawl or walk down the ramp (Adolph, 1997; Adolph et al., 2008; Tamis-LeMonda et al., 2008). The presence of water on the slope poses a different risk to infants; it offers a smooth and gradual transition from a safe to an unsafe zone. In contrast to the Water Cliff, where going further means a sudden fall into the water, on the Water Slope the ramp leads the infants deeper and
deeper into the water and they have to reevaluate their possibilities for action and the consequences of going further at each step.

While the Water Cliff represented an impossible drop-off filled with water, it is possible that the presence of water on a safe to navigate dryland slope (i.e., Water Slope) would represent an ambiguous situation to the infants. Previous studies have shown that when infants are uncertain about the risk of a drop-off, they may rely on mothers’ social information (e.g., Sorce et al., 1985; Tamis-LeMonda et al., 2008; Adolph et al., 2008; Karasik, Tamis-LeMonda and Adolph, 2016). When infants were tested on 0 to 50° slopes experienced walkers only used mothers’ social information (encouragement or discouragement) at the boundary slopes, refusing to descend risky slopes even when mothers were encouraging them (Tamis-LeMonda et al., 2008). Experienced crawlers only relied on mothers' social information on safe to navigate slopes, refusing to crawl down borderline and risky slopes (Adolph et al., 2008) and novice walkers attempted descending both safe and risky slopes, 75% of them attempting to walk down impossible 50° slopes in the encouraging condition (Adolph et al., 2008). Therefore, if the Water Slope offered ambiguous information to the infants, because the mothers were encouraging them to go on, we would expect walkers (novice and experienced) to reach the submersion point and experienced crawlers to avoid it. This was not the case. Clearly, then, further investigation is needed to determine if positive or negative social information offered by the mothers affects infants' behaviour on the Water Slope.

Infants’ more accurate behaviour on the Water Cliff, in contrast to the Water Slope, is in accordance with previous studies showing that infants with considerable locomotor experience were capable of adapting their behaviours to avoid situations where the perceived penalty of going further could be severe, such as falling from cliffs (e.g.,
Campos, et al., 1992; Adolph, 1997; Kretch & Adolph, 2013; Burnay & Cordovil, 2016; Burnay et al., 2020) or into a body of water (Burnay & Cordovil, 2016; Burnay et al., 2020). Less accurate behaviour was reported when the consequences of injuries were less significant, as when negotiating apertures (Franchak & Adolph, 2012), walking compared to running under barriers (van der Meer, 1997), or going up slopes compared to going down (Adolph, 1997).

If crawlers cannot safely crawl down a dryland slope, they can shift to a sliding solution and if walkers cannot safely walk down a slope, they can shift to a crawling or sliding solution. However, shifting from a crawling to a sliding posture or from an upright to a sitting or crawling posture does not help infants to safely navigate increasingly deep water, it only increases the risk of submersion. In addition, although the 10º slope is safe to crawl or walk down on dryland, when it led to deep water some crawlers and most of the walkers that reached the submersion point did so by falling into the water, highlighting the dangers of sloped accessways to bodies of water.

It would be expected that avoiding infants would cautiously approach the water, retreat or show signs of distress when they perceived the water was not safe. However, the variables indexing these behaviours were inconclusive. Although non-avoiders approached the water faster than avoiders, the approaching time was highly variable and statistically there were no differences in the time avoiders and non-avoiders took to approach the water. In addition, the effect of locomotor experience on the approach time was the opposite for crawlers and walkers: crawlers with more crawling experience approached the water faster and walkers with more crawling experience approached the water more slowly. With respect to the retreat behaviour, avoiding infants shied away from the water after touching it more than non-avoiders. However,
after crossing the water line, most avoiding and non-avoiding infants did not retreat from the water; they simply stood in the water, exploring and playing, enhancing the risk of engaging in drowning incidents, even for those who managed to avoid the submersion point.

Only 30% of the infants showed signs of distress during the testing and there was no difference in the percentage of avoiders and non-avoiders that did so. In addition, the moments infants showed signs of distress were quite variable and the number of infants that started showing signs of distress after crossing the water line was too small (14) invalidating any conclusions about a critical depth at which infants would perceive the water as dangerously deep.

The findings reveal new insights into the risks bodies of water pose to mobile infants, particularly when easy access to the water is available, but they also raise important questions. A systematic program of research is needed to understand the generalizability of the current findings to other settings and age ranges and to tease out the reasons many mobile infants seem so cavalier about entering bodies of water. It is not clear what affordance(s) infants are acting upon when they venture up to a submersion point or what types of experience are necessary to perceive the underlying affordance(s). Do infants fail to perceive they cannot crawl or walk on water? Do they fail to perceive they cannot float or swim? Do they fail to perceive that deep and shallow water offer very different possibilities for action? Does a sloped entrance to the water just represent an ambiguous situation that infants fail to perceive as risky? It is also important to acknowledge that 30-40% of infants avoided reaching the submersion point. What accounts for their behaviours? Clearly, locomotor experience does not explain it. Have these infants had other experiences that account for their greater
caution? What types of experience might make them more cautious around bodies of water? Are these infants temperamentally different from the non-avoiders? Regardless of the answers to these questions, pursuing them systematically could make a major contribution to our understanding of the development of perception and action and to the design of strategies to minimize drowning incidents, both of which would benefit society significantly.

Limitations

The Real Cliff / Water Cliff studies (Burnay & Cordovil, 2016, Burnay et al., 2020) were conducted in Lisbon, Portugal, while the Water Slope study took place in Dunedin, New Zealand. The possible cross-cultural effect is not clear and needs to be further investigated. A future study should compare the same infants on the water cliff and water slopes paradigms within the same experiment to overcome the limitations associated with making comparisons across experiments conducted at different times in different places.

Usually, the slope to access swimming pools is smaller than 10°. For instance, the New Zealand government indicates 4.76° as the maximum slope to be used in swimming pools designs (New Zealand Standards, 2008). Because such a shallow slope was difficult to replicate in laboratory, the 10° slope was used (being smaller than the slope boundary for infants to safe locomote in dryland). Further investigation is needed to analyse if shallower slopes would have different effects on infants’ behaviour when accessing bodies of water.
CONCLUSIONS

The findings indicate that locomotor experience has no influence on infants' perception of bodies of water as a risky environment that should be avoided. The results also point to an enhanced risk of infants engaging in drowning incidents when the accessway to a body of water is smooth and gradual (i.e., shallow ramp) than when it affords a sudden fall into the water (i.e., drop-off). These findings highlight the dangers zero entry pools pose to mobile infants, a danger that likely extends to any body of water that can be accessed via a gentle slope, like a beach or a boat ramp. The designers of zero-entry pools may need to consider the need for clear signage and supervision restrictions to help prevent drowning tragedies from occurring.

REFERENCES


INFANTS’ AVOIDANCE OF WATER SLOPES


