TIME PERCEPTION IN THE DEEP BLUE SEA

Sharon Lipperman-Kreda and Joseph Glicksohn
Department of Criminology,
and The Leslie and Susan Gonda (Goldschmied)
Multidisciplinary Brain Research Center,
Bar-Ilan University
Ramat Gan, 52100, Israel
E-mail: sharon_kreda@yahoo.com; chanita@bgumail.bgu.ac.il

Abstract

With increasing depth, underwater performance is impaired, presumably because of a general slowing down of the internal clock. If the internal clock slows down, then produced duration should be longer. We contrasted time production in shallow diving (<10m) and in depth diving (>30m). The study was carried out in the Red Sea, which has a constant temperature of 21 to 22°C, and which provides comfortable diving conditions. A total of 17 trained divers, 15 male and 2 female, ranging in age between 24 and 38 years, completed the task both under water and on dry land (our Context factor). A two-way analysis of variance (ANOVA) on mean produced duration supported an additive model, whereby the main effect of Context was significant and that of Depth was marginally significant. We suspect that Context and duration might interact at the individual level, as can be seen for some of the participants.

Thirty years ago, a distinction drawn in the literature between physiological and cognitive models of time perception was still popular (Block, 1979; Ornstein, 1969). The physiological model implied a biological pacemaker, or 'internal clock' (Hoagland, 1933; Treisman, 1963); the cognitive model was memory-based (Block, 1979), in line with the ascendancy of an information-processing approach. One of the reasons for the demise in popularity of 'internal clock' models was Ornstein's (1969) dismissal of them, and his proposal of a highly-cited cognitive model, paving the way for Block's (1979, p. 195) contextual-change hypothesis. Proponents of a hybrid, 'cognitive-timer' (Zakay, 1989)—which involved memory, attention and more importantly a return to the notion of an 'internal clock'—were notably gaining ground, even while Block (1990, p. 18) suggested that "Internal-clock models seem best suited to handle relatively simple relationships, such as that between body temperature, arousal, and response rate". Given the fact that both internal-clock and contextual-change notions have been wedded in the very prominent attentional-gate model, proposed by Zakay and Block (Zakay & Block, 1997, 2004), it is perhaps time to reconsider Block's (1990) comments.

First, the cognitive-timer/attentional-gate model should be well able to handle such a simple relationship as that pertaining to the influence of body temperature (Hancock, 1993; Jamin *et al.,* 2004; Miró, Cano, Espinosa-Fernández, & Buela-Casal, 2003; Wearden & Penton-Voak, 1995) and/or arousal level (Gruber & Block, 2003; Ozel, Larue, & Dosseville, 2004; Penton-Voak, Edwards, Percival, & Wearden, 1996; Treisman & Brogan, 1992) on internal clock rate. Our task will be that of time production, completed under water, with all that pertains to that type of situation (Brooke & Ellis, 1992; Nevo & Breitstein, 1999; Tetzlaff & Thorsen, 2005). We adopt the working hypothesis that with increasing depth, performance becomes impaired (Kiessling & Maag, 1962, p. 94; Phillips, 1984, p. 646), presumably because of a general "slowing down" (Brooke & Ellis, 1992, p. 180). We view this as implicating the slowing down of the internal clock. While Baddeley (1966b) reported that reduced body temperature (i.e., diving in cold water, at 4°C) slowed down the internal clock, that is his participants "counted more slowly ... as Hoagland's hypothesis would predict ...." (p. 476), he later surprisingly argued that "the effect of cold on time estimation, observed by Baddeley (1966) is hard to interpret since we know virtually nothing of the process, central or peripheral, on which time estimation is based" (Baddeley, Cuccaro, Egstrom, Weltman, & Willis, 1975, p. 453). Of course, we cannot agree here, for if the internal clock slows down, then produced duration should be longer (Glicksohn, 2001). Secondly, getting back to Block (1990), we can provide a very clear degree of change in cognitive context in the present study, because our participants will complete the task both on land and under water, as in previous studies (Baddeley, 1966b; Phillips, 1984, p. 646). Furthermore, we could contrast time production in shallow diving (up to 10m) and in depth diving (in excess of 30m)—the latter implicating the influence of nitrogen narcosis when diving using compressed air (Brooke & Ellis, 1992; Nevo & Breitstein, 1999).

Produced time (*P*) will be compared with target duration (*D*), by means of the log-transformed psychophysical function. The multiplicative model for apparent duration (Glicksohn, 2001), which relies on the architecture of the attentional-gate model, makes the specific prediction that it is the intercept of the log-transformed psychophysical function which is the locus for both interindividual and contextual differences (Glicksohn, 2003, 2004). Here, we shall also explore intraindividual differences with the same notion in mind.

Method

Participants and Setting

The study was carried out in the Red Sea, which has a constant temperature of 21 to 22°C, and which provides comfortable diving conditions. A total of 17 trained divers, 15 male and 2 female, ranging in age between 24 and 38 years, participated in the study.

Time Production

Four short intervals of 4, 8, 16 and 32 seconds served for the time-production task. The participant was required to estimate each of these intervals by signaling to the experimenter (who held a stopwatch) the estimated period of time (method of production). Each interval was produced once under water, and once on land. Produced and required durations were log-transformed (to base 2), with required durations rendering thereby a linear scale ranging between 2 and 5, with a midpoint value of 3.5; produced duration was then regressed on required duration. The slope of this function, which expresses the exponent of the psychophysical function was derived, as was the intercept of the function. In addition to these measures, mean produced duration was also computed for comparison with the data of previous studies (Glicksohn, 1992, 1996, 2003, 2004).

Procedure

Our participants completed the time-production task once on land, and once under water (using compressed air), with 5 of the participants completing these in this order, and 12 in the other order. Ten of the participants completed the task at a depth of up to 10m, while the other 7 completed the task at a depth in excess of 30m. The experimenter who collected these data was a professional diver, having rich diving experience, who was blind to the goals of the study. For the experiments under water, we prepared a plastic board with 4 different series of the 4 times to be produced, held by the experimenter. Each participant received a different series. By using agreed signs, the experimenter could ask the diver to produce the requested time by indicating to him when to repress a stopwatch. He then wrote the produced times on the board under water, and subsequently copied the data to a table when on shore. Time production on land took place a few hours either before or after the dive, in the same manner.

Results and Discussion

One participant exhibited irregular data, and was therefore excluded from the analysis. Inspection of the individual psychophysical functions confirmed the linearity assumption for all remaining 16 individuals, r^2 values ranging between 0.978 and 0.999 on land, and between 0.985 and 0.999 under water. If the internal clock slows down under water, then one would expect to see longer time productions under water, relative to on land—our Context factor. Table 1 provides individual data, and reveals that the Context effect is found for 10 of the 16 divers. Furthermore, if the internal clock slows down as a function of depth, then this effect will be more pronounced at a depth in excess of 30m. A two-way analysis of variance (ANOVA) on mean produced duration supported such an additive model, whereby the main effect of Context was supported [$F(1, 14) = 4.72$, $p < .05$], while that of Depth [$F(1, 14) = 4.39$, $p = .055$] was marginally significant.

Table 1. Individual mean, slope and intercept values for diving and dry land conditions

Diver	depth	M_{diving}	M_{dry}	$slope_{diving}$	$slope_{dry}$	$intercept_{diving}$	$intercept_{dry}$
9	9 m	3.777	3.370	1.125	1.131	-0.160	-0.590
5a	5 m	3.452	3.252	1.019	1.067	-0.116	-0.482
6	6 m	3.759	3.277	0.831	1.097	0.850	-0.561
5b	5 m	3.452	3.325	1.019	0.950	-0.116	0.000
5	5 m	2.620	2.244	1.148	0.732	-1.400	-0.317
9a	9 m	3.244	3.255	1.108	0.892	-0.634	0.135
5d	5 m	3.402	3.393	1.102	0.967	-0.454	0.007
5c	5 m	3.280	3.461	1.170	1.049	-0.815	-0.210
5f	5 m	3.209	3.233	1.060	1.133	-0.500	-0.733
5g	5 m	3.280	3.373	1.170	1.115	-0.815	-0.530
$M_{< 10 m}$	**6.5 m**	**3.347**	**3.218**	**1.075**	**1.013**	**-0.416**	**-0.328**
37	37 m	4.019	3.373	0.809	1.097	1.187	-0.465
36	36 m	3.759	3.519	0.969	1.042	0.616	-0.127
40a	40 m	3.666	3.519	1.082	0.955	-0.121	0.176
40b	40 m	3.048	3.302	0.933	1.107	-0.216	-0.571
40	40 m	4.095	3.741	1.143	1.081	0.095	-0.044
37a	37 m	3.522	3.634	1.026	0.900	-0.070	0.485
$M_{> 30 m}$	**38.3 m**	**3.685**	**3.515**	**0.994**	**1.030**	**0.248**	**-0.091**

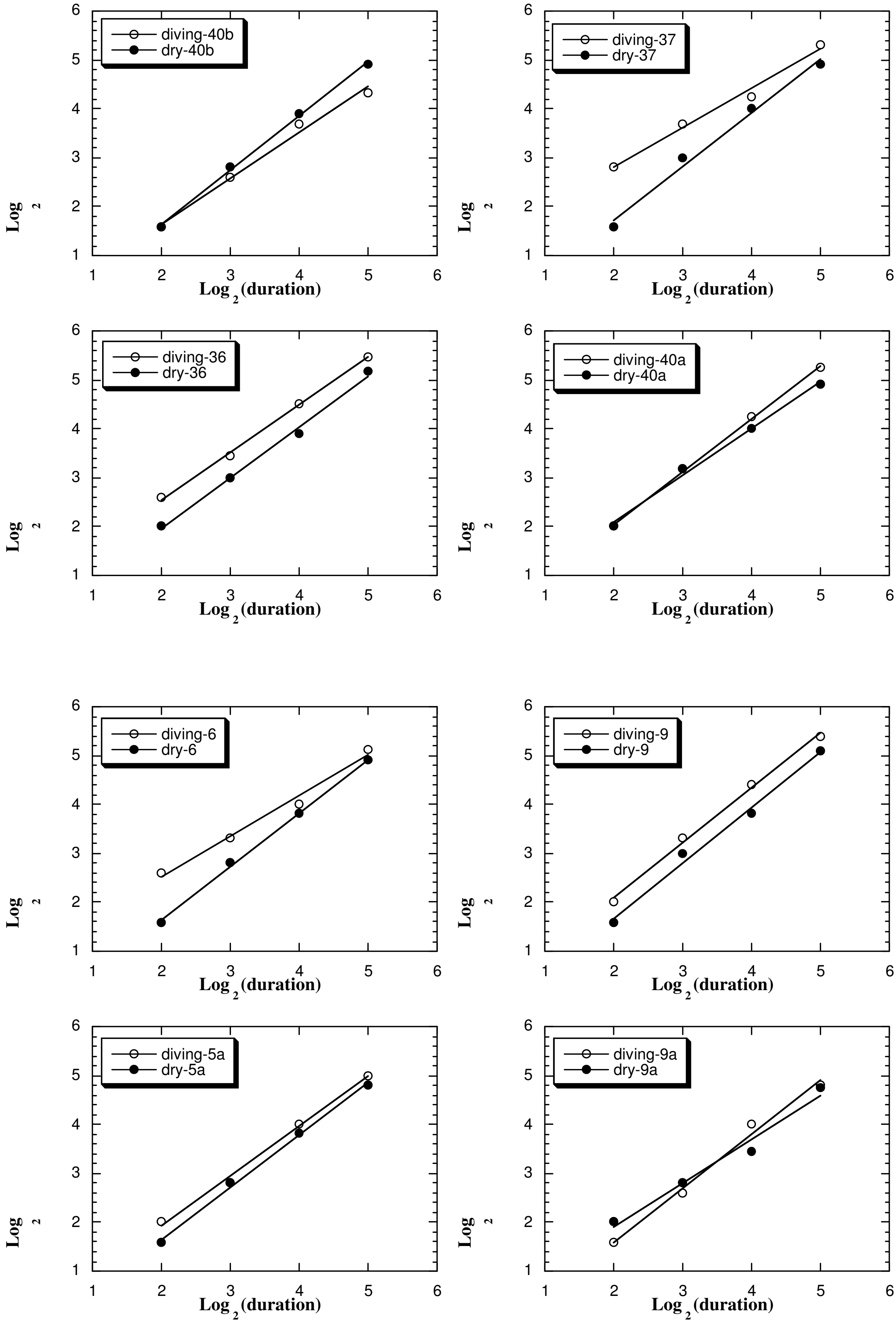

Figure 1. Select individual data for underwater and dry land conditions

A similar ANOVA run on the slope [$F(1, 14) < 1$], ruled out a difference in exponent, while a comparable ANOVA run on the intercept strengthens the effect for Depth [$F(1, 14) = 9.15$, $p < .01$], but negated that of Context [$F(1, 14) < 1$]. We suspect that Context and duration might interact at the individual level, as can be seen for some of the participants (see Figure 1). Clearly we need more data here—more sessions for each diver, and more divers.

It is important to note that relatively little research has been carried out in the open sea (Phillips, 1984) and that many studies are performed in a dry air pressure chamber (Abraini, 1997; Charles, Allimann, & Ragot, 2001; Pastena, Faralli, Mainardi, & Gagliardi, 2005). The question is still raised as to how valid the results that stem from that environment are compared with the open sea (Baddeley, 1966a; Brooke & Ellis, 1992; Phillips, 1984). Indeed, some investigators specify the influence of the water itself on cognitive performance, unrelated to hyperbaric pressure (Nevo & Breitstein, 1999). Given the paucity of data on time estimation under water, we are currently continuing this line of research.

References

Abraini, J. H. (1997). Inert gas and raised pressure: Evidence that motor decrements are due to pressure per se and cognitive decrements due to narcotic action. *European Journal of Physiology, 433*, 788-791.

Baddeley, A. D. (1966a). Influence of depth on the manual dexterity of free divers: A comparison between open sea and pressure chamber testing. *Journal of Applied Psychology, 50*, 81-85.

Baddeley, A. D. (1966b). Time-estimation at reduced body-temperature. *American Journal of Psychology, 79*, 475-479.

Baddeley, A. D., Cuccaro, W. J., Egstrom, G. H., Weltman, G., & Willis, M. A. (1975). Cognitive efficiency of divers working in cold water. *Human Factors, 17*, 446-454.

Block, R. A. (1979). Time and consciousness. In G. Underwood & R. Stevens (Eds.), *Aspects of consciousness, Vol.1: Psychological issues* (pp. 179-217). London: Academic Press.

Block, R. A. (1990). Models of psychological time. In R. A. Block (Ed.), *Cognitive models of psychological time* (pp. 1-35). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Brooke, S., & Ellis, H. (1992). Hyperbaric environments. In D. M. Jones & A. P. Smith (Eds.), *Handbook of human performance, Vol. 1: The physical environment* (pp. 177-209). London: Academic Press.

Charles, A., Allimann, F., & Ragot, P. (2001). Diving and cognitive performance: The selective impairment of control processes. In F. Columbus (Ed.), *Advances in psychology research* (Vol. 2, pp. 186-192). Huntington, NY: Nova Science.

Glicksohn, J. (1992). Subjective time estimation in altered sensory environments. *Environment and Behavior, 24*, 634-652.

Glicksohn, J. (1996). Entering trait and context into a cognitive-timer model for time estimation. *Journal of Environmental Psychology, 16*, 361-370.

Glicksohn, J. (2001). Temporal cognition and the phenomenology of time: A multiplicative function for apparent duration. *Consciousness and Cognition, 10*, 1-25.

Glicksohn, J. (2003). Disentangling the components of a multiplicative function for apparent duration. In B. Berglund & E. Borg (Eds.), *Fechner Day 2003: Proceedings of the Nineteenth Annual Meeting of the International Society for Psychophysics* (pp. 109-114). Stockholm: International Society for Psychophysics.

Glicksohn, J. (2004). Sex differences in prospective timing: Can one pinpoint the effect? In A. M. Oliveira, M. Teixara, G. F. Borges, & M. J. Ferro (Eds.), *Fechner Day 2004: Proceedings of the Twentieth Annual Meeting of the International Society for Psychophysics* (pp. 152-157). Coimbra: International Society for Psychophysics.

Gruber, R. P., & Block, R. A. (2003). Effect of caffeine on prospective and retrospective duration judgements. *Human Psychopharmacology: Clinical and Experimental, 18*, 351-359.

Hancock, P. A. (1993). Body temperature influence on time perception. *Journal of General Psychology, 120*, 197-216.

Hoagland, H. (1933). The physiological control of judgments of duration: Evidence for a chemical clock. *Journal of General Psychology, 9*, 267-287.

Jamin, T., Joulia, F., Fontanari, P., Giacomoni, M., Bonnon, M., Vidal, F., & Crémieux, J. (2004). Apnea-induced changes in time estimation and its relation to bradycardia. *Aviation, Space and Environmental Medicine, 75*, 876-880.

Kiessling, R. J., & Maag, C. H. (1962). Performance impairment as a function of nitrogen narcosis. *Journal of Applied Psychology, 46*, 91-95.

Miró, E., Cano, M. C., Espinosa-Fernández, L., & Buela-Casal, G. (2003). Time estimation during prolonged sleep deprivation and its relation to activation measures. *Human Factors, 45*, 148-159.

Nevo, B., & Breitstein, S. (1999). *Psychological and behavioral aspects of diving*. Flagstaff, AZ: Best Publishing Company.

Ornstein, R. E. (1969). *On the experience of time*. Harmondsworth, Middlesex: Penguin.

Ozel, S., Larue, J., & Dosseville, F. (2004). Effect of arousal on internal clock speed in real action and mental imagery. *Canadian Journal of Experimental Psychology, 58*, 196-205.

Penton-Voak, I. S., Edwards, H., Percival, A., & Wearden, J. H. (1996). Speeding up an internal clock in humans? Effects of click trains on subjective duration. *Journal of Experimental Psychology: Animal Behavior Processes, 22*, 307-320.

Phillips, C. J. (1984). Cognitive performance in sports SCUBA divers. *Perceptual and Motor Skills, 59*, 645-646.

Tetzlaff, K., & Thorsen, E. (2005). Breathing at depth: Physiologic and clinical aspects of diving while breathing compressed gas. *Clinics in Chest Medicine, 26*, 355-380.

Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock". *Psychological Monographs: General and Applied, 77,* (Whole no. 576).

Treisman, M., & Brogan, D. (1992). Time perception and the internal clock: Effects of visual flicker on the temporal oscillator. *European Journal of Cognitive Psychology, 4*, 41-70.

Wearden, J. H., & Penton-Voak, I. S. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *Quarterly Journal of Experimental Psychology, 48B*, 129-141.

Zakay, D. (1989). Subjective time and attentional resource allocation: An integrated model of time estimation. In I. Levin & D. Zakay (Eds.), *Time and human cognition: A life-span perspective* (pp. 365-397). Amsterdam: Elsevier Science Publishers.

Zakay, D., & Block, R. A. (1997). Temporal cognition. *Current Directions in Psychological Science, 6*, 12-16.

Zakay, D., & Block, R. A. (2004). Prospective and retrospective duration judgments: An executive-control perspective. *Acta Neurobiologiae Experimentalis, 64*, 319-328.