Adaptive 3D Printed Depth Gauge for People with Visual Impairment in Inclusive Scuba Diving to Enhance Safety

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Abstract

Background: There is a growing number of visually impaired individuals exploring the underwater world through scuba diving. However, most of the existing scuba equipment is not user-friendly for people with visual impairment. Visually impaired divers typically rely on dive guides who signal depth and other information by touch (e.g., pinching to indicate approximate depth). These methods are imprecise, non-linear, and reduce the diver's autonomy and enjoyment of underwater exploration. Also, they often have difficulty maintaining a 3-6-meter depth safety stop, a procedure used to reduce the risk of decompression sickness.

Method: A tactile depth gauge was designed by integrating a standard syringe with a custom 3D-printed device that functions as a tactile depth scale. External hydrostatic pressure pushes the syringe plunger into the barrel as depth increases; because ambient pressure rises by roughly 1 atmosphere per 10 m of seawater, plunger position can be mapped to depth. The syringe plunger total stroke length is 7.0 cm; measured correspondences are approximately: hydrostatic pressure of water at 3 meters depth equaled to syringe length 5.4 cm, 6 meters equaled to 4.4 cm, 10 meters equaled to 3.5 cm, 15 meters equaled to 2.8 cm. The device was printed with a dual-extruder printer at 100 µm layer resolution using Acrylonitrile Styrene Acrylate (ASA) filament as ASA has excellent UV and weather resistance, good mechanical strength and low water uptake behavior. The printed device contains tactile ridges aligned to the plunger to form a physical depth scale. The assembly was tested to withstand at least 20 m water pressure. The tactile depth gauge was attached with two rubber bands and strapped on diver's forearm

Results: Three visually impaired recreational divers trialed the device in ocean environment. All reported positive feedback in a questionnaire form: increased sense of autonomy, clearer interaction with the underwater environment, and greater enjoyment of the dive compared with traditional guide-dependent signaling.

Conclusion: The 3D-printed tactile depth gauge integrated with a syringe offers a simple but reliable aid that improves the diving experience and also safety for scuba diver with visual impairment. Future work will explore additional adaptive aids to further enhance participant with visual impairment in independent underwater navigation and exploration.