Systematization of the Knowledge of Relevant Signals in Evaluating the Surf Zone

Proficiency in Positioning in the Surf Zone Lineup and in Wave Catching

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Keywords: Safety, Coastal Currents, Surf, Systematics, Wave Knowledge, Lineup, Patterns.

Abstract: Regarding the beach safety of surf zone users, this study aims to systematize the "Wave Knowledge" of the most efficient lifeguards, the surfing masters, by classifying the indicators relevant for recognizing spacial and temporal patterns and risk factors. This is evidenced by the proficiency in motor tasks essential both to the sport and rescuing in the surf zone: positioning in the lineup, catching waves/ returning to shore (when "Wave judgement" is needed). We start by reviewing the literature from Surf Sciences, followed by an analysis of manuals of Surfing as a sport. Then we researched the prospective procedures of experts in extreme surf conditions and observed behaviour of top surfers in competition, to put up a classification of the visual signs used (sea and swell, wind, tide, seabed configuration, currents, and details of breaking waves' forms). Based on the acquired data, we built a Questionnaire to rank the "relative importance of the signals", which surveyed 11 surf national champions/ coaches (male/female practitioners with over 15 years' experience). Results show that experienced surfers evaluate all elements of the "waves-currents system", although the location, type and intensity of maritime currents (except under conditions of small waves), and the swell characteristics (angle of arrival to coast, height, period) stand out as the most important. The importance of the signals varies according to the wave height and the wave break types. The respondents also attend configuration of seabed and coast profile in their evaluation. As for the surf quality, they consider the characteristics of the coastal wind and temporal characteristics of the tides. For the strength of the surf and the take-off point, the focus is on sections and wave face profiles (slope, thickness).

1 INTRODUCTION

1.1 Symposium Technology in Surfing

Paper made for *TechSurf*, Congress "Sports Science Research and Technology Support icSPORTS2013", 21 Sept Portugal. Master thesis presented in Faculdade de Motricidade Humana, 21 July 2011.

May it contribute "For others may live", motto that my father flew in FAP. Professor Peixoto made it possible. Greetings to the expert surfers inquired. Mother, thank you. Love, beautiful Cecília. To Joana: love you, dearest daughter, fight for dignity!

Figure 1: Observe, research, systematize, teach, compete.

1.2 Foreword: Unacceptable Mass Drownings in Surf Bathing

In this study we approached the problem of safeguarding human life when bathing/ swimming in our Portuguese sea, from the perspective of the most efficient lifeguard – the very experienced and informed surfer, used to big waves, with exceptional fitness. "[Hawaiian, North Pacific] Surfers made the best lifeguards because they have experienced first-hand how powerful the ocean can be. They also knew the most about its many variables, including waves, wind conditions, currents, rip tides, channels and shore breaks"; "people who understand the ocean and are not afraid of it" (Coleman, 2001). In Oceanic coastline, where all environment elements are commonly present with uncontrollable forces (and occasionally brutal, by conjunction of variables that to the layman tourist look ordinary), these wave runners possess a practical knowledge about the Ocean's wave-currents dynamics in the wave

Brogueira, J. and Peixoto, C..
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In *Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support (icSPORTS 2015)*, pages 104-118
ISBN: 978-989-758-159-5
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breaking coastal zones ("surf zones"), which is fundamental in Beach Safety and in Sea Rescue. In Portugal [North Atlantic] the "surfer lifeguard" brought new knowledge and practices that were applied from 1973 in "new methods and equipment" in rescue practices. This resulted in no more drownings in beaches where it was frequent. "The choice of lifeguards surfers is an added value to any beach on the Atlantic coast", "a sea with strength and currents, unpredictable and where we find changes in the currents, the size and strength of the waves in just a few hours" (Rocha, 2008).

These experienced sporting watermen, "extremely proficient ocean swimmer and surfer […] who can make informed decisions and predetermine the level of risk they will face" (Guisado, 2003), "know how to identify, to anticipate and to explain the risks" (Coleman, 2001), are the most capable and competent rescuers (Surf Life Saving Association of Australia, 1975). In these conditions, the understanding of the phenomena, a good knowledge of surf conditions, is vitally important to all surfers (Orbelian, 1982) (Somers, 1988) (Lowdon, 1988) (Noll and Gabbard, 1989) (SLSAA, 1974) (Collins, 1992) (Dupouey, 1997) (Jenkins, 1993) (Butt, 2002) (Colburn et al, 2002) (Slater & Borte, 2003). Aware of the importance of "playing by the ocean's rules", expert surfers pass on this Wave Knowledge and "sea reading" ability, in each surf spot, to their infants and local peer group (Carroll, 1994) (Young, 2003) (Hall, 2004) (Rocha, 2008) (Pereira, 2001) (Jarvis, 2004). "The best surfers learn from the very best, growing up immersed in a multi-generational culture of complete ocean awareness" (Slater, 2005).

Among beach users, this "awareness" is misunderstood; these "secrets of the sea" are complex and not obvious. The urban common sense and the general teachings of classic mechanics are inappropriate in the Portuguese coast bathing zones, a chaotic system with ocean waves and currents. Here wave heights remain above 1 meter for 95% of the year, and above 4 m for 5% of the year (Instituto de Meteorologia, 2007). Moreover, some natural environments, like high-mountain, rafting waters, scuba-diving depths, and surf zones, require being aware that human technology and intellect cannot domesticate the forces in presence. Nature, although accessible in artificial coastal zones (of banal urbanization and coastal compression), is wild. When facing a challenge with a danger level beyond one's competences (knowledge, skills, aptitudes), there must be full consciousness that, by insisting, the experience may become adverse or even disastrous and tragic (Swarbrooke, 2003). In this leisure practice of surf bathing, it is fundamental, vital, to be informed and aware of the risks, being able to identify the intensity and dynamics of nature's forces present, as well as the hazardous places (Surf Life Saving Association of Australia, 1974). The flat water swimming skills and swimmers' physical fitness are not enough to ensure the ability to return to the coast, as the Portuguese Lifeguard Manual advises (Pereira, 2001).

1.3 Surfing, Best Surfer, Surf Master

In sporting terminology the correct and officially admitted vocabulary is necessary, as it allows to convey precisely all the technical elements. The words must be accurate to avoid misunderstandings from practitioners and technicians, "or even in the translation of a text" (Peixoto, 1993). A section is dedicated to operational definitions to define the problem, in the full text of the thesis. All expressions or terms in any form considered technical (i.e. not generally known) appearing in the problem are defined, as the investigator considers it. Any ambiguous term, or a special meaning in the context of this study, albeit in common use, are clarified.

"Surfing breaks have great social and economic value for coastal communities. In order to preserve and enhance these resources, a common language is needed that will bridge the gap between the colloquial slang of surfers and the technical language of scientists and policy makers. This language is the science of surfing waves and surfing breaks" (Scarfe & al, 2003).

This short paper does not include the revisions of the subjects Oceanography, Meteorology, Hydrography and computer Modelling concepts regarding physical wave elements, maritime wave formation and propagation, winds, sea ripples and fetch, the phenomena of offshore swell characteristic properties (reflection, refraction, diffraction, interference) and coastal waves characteristic properties (shoaling, refraction, diffraction), coastal processes, wave-currents system and equilibrium beach profiles, tide elements, seabed, seasonal beach profiles, erosion and coastline, categorized types of surfing breaks, main surfing wave parameters ("*surfability*"), artificial reef breaks, maritime agitation characteristics in the Portuguese coast, and temporal conjunction effects (like coastal jets, rogues, exceptional wave sets, onshore wind setup, storm-surge, spring tides, current effects). They can be consulted in the thesis.

1.3.1 True Surfing

Surf in the English language designates the maritime surface waves breaking in coastal zone (breakers). In Portuguese *Surf* designates the Surfing sport itself, *Surfe* is used in Brazilian.

The "To surf" definition must be considered, since it concerns the essence of the proficiency studied. This is the sport of surfing (*he'e nalu* (wave-sliding), surf-bathing, Hawaiian sport of surf playing, swell driving, surf riding, surf board swimming, wave-riding, surfing). "Surfing is the sport of riding across the face of a wave while standing on a specialized board" (Orbelian, 1982) "The art of standing up while riding diagonally across a wave front" (Finney & Houston, 1996); "Travel on the wave […] slide on the wall of the wave, […] towards the beach" (Moreira, 2007). Therefore, it should be clear that any Surfer is always referring to a wave face ride (Finney&Houston, 1996) (Young, 1983) (Pukui, 2003) (Warshaw, 2005), never to a straight-off ride on the white-water wash of the collapsed wave. We also refer to the judging rules: "The contestant that systematically chooses the waves that close out should be penalized (in the score) for having choice and acting against the spirit of surfing" (Jonet, 1989). Catching a wave means a controlled descent through turns, travelling/cutting the wall of wave, i.e. in nautical terms manoeuvring. This greatly reduces the location of quality peaks, and the opportunities for surfing (good waves available from the whole sets).

It has huge implications on proficiency, for the outside must be reached, and the lineup must be read, to find the first take-off zone (the point where the swell collapses to become surf): they have to deal with the currents and the possibility of not being able to catch waves (i.e., returning to shore!). Very strong indignation was caused by tourists bragging of being surfers when poorly riding in white-water from small broken waves, while they understood nothing of the Ocean (Crowe, 2002); so in 1911 native Hawaiians revived the practice of "true surfing", in the organized form of a the *Hui Nalu club* (Finney&Houston, 1996) (Hall, 2004).

1.3.2 Surf Master's Expertise

"A masterful surfer is a product of (usually) around 20 years of concerted, directed effort, a hundred different surf spots, several hundred boards and a couple of hundred thousand waves" (Carroll, 1994). Mastery in surfing is a result of refining the general knowledge of the surf dynamics; it derives from "local wave knowledge"; and it allows efficiency through conjunction to surf energies. "All beaches are different and each surfer is the individual able to realize the surrounding situation" (Amaro, 1989). This "experience and expertise to handle the big surf" (Coleman, 2001), or "most masterful surfer" (Melekian, 2004), differs from the daily tricks performance from the "best surfer/ most skilful". Surf Masters are the experts who are relevant to observe and question in order to record their procedures in surf reading, so that we have a chance to organise this wave knowledge. "Every surf spot will have its own characteristic wave, which will change according to tide, swell, and wind" (Orbelian, 1982). "[D]ominance is ability supplemented by knowledge. Knowledge developed over time. Knowledge acquired by consistency." (Melekian, 2004).

2 OBJECTIVES

We aim to classify and systematize the expert surfer's wave knowledge, "using objective, accessible, exact, concise sport terminology" (Peixoto, 1993).

The goal is to understand and organise the surfing master's knowledge about the surf and currents, so that information for spacial and temporal pattern recognition at sea, surf and currents may become public, having a practical application for Beach Safety.

2.1 Starting Question and Problem

In order to fit the line of investigation, an initial, very broad, question arose to review the knowledge already produced about the various areas of study: 'It is possible to systematize the knowledge about the surf zone that defines surfer's proficiency, whether in sports practice or in sea rescuing?'

The Problem consists simply in an expansion of the study title ('Surf Masters: Systematization of the knowledge of relevant signals in evaluating the surf zone') presented as this general statement: 'the goal/ purpose of this research is human life safeguard, systematizing the practical surf zone knowledge that defines a surfer's proficiency, knowledge used to evaluate the surf conditions, find and catch the surf, by using the relevant visual signals from the waves-currents system'. We question the most efficient lifeguards in beaches with surf, and analyse the motor tasks essential both to the sport and surf rescuing.

"Wave judgement is the most difficult aspect of surfing to master. It takes years to accumulate the experience needed to deal with the multitude of situations the sea is capable of" (Orbelian, 1982). We research into the possibility to systematize the surfer's "wave knowledge" about wave-currents dynamics in the surf zone by using a classification of the relevant signals from the coastal process (dynamic, non-linear). For risk assessment, the game rules, the context evaluation, the "ocean reading" ability, the "wave knowledge" skills: "Which are visual cues that enable evaluating the variables specifiers of the characteristics of waves and currents, and especially which are relevant to the surfing conditions at hand?".

"Most accomplished big wave riders are in their thirties. It takes a long time to build the experience and, mainly, the judgement required to ride big waves" (Ricky Grigg, in Noll & Gabbard, 1989). The associated problem is the "wave judgement", skill necessary to catch waves: "Which are the relevant signals about the surf shape characteristics, to evaluate the plan where the breaking wave passes, and its profile and strengths?".

2.2 Pertinence and Complexity

"The area of the coast where the waves break is one of the most difficult maritime regions to study due to the high intensity and non-linearity of the waves and currents. Beyond the scientific interest motivated by open issues, it is a strip that we need to understand, that it is crucial to coastal erosion, dissipating wave energy, coastal works, sediment transport, pollutant dispersion, surfing and safety of swimmers and boats" (Bicudo, 2007).

The task of reading and understanding the ocean waves ("observe, analyse, decode, compare and deduce"), is ambitious, "somewhat foolish for the extreme complexity involved" (Dupouey, 1997). We pursue an original task of explaining the reading of the signals picked up on the ocean coastal waves and currents dynamics; parameterizing objectively the essence of a shared collective consciousness (Slater, 2005). And by doing it in a maritime population that share a feeling of competition among themselves, cohesive and used to live in uncertainty and danger (Moreira, 1987), for whom any spreading of the "local wave knowledge" (such as surf-travel guidebooks, surf-reports, surf-trip diaries) is "regarded by many surfers as nothing less than heretical, as it revealed in just a few short pages information that had taken local surfers years to accumulate" (Warshaw, 2005). Even in lifeguard courses, it is advised to have "practical experience in surfing" in order to acquire this "knowledge and experience from spending many hours in surfing", and "discussion with old hands" is also suggested (Surf Life Saving Association of Australia, 1975). In Portuguese Lifeguard Manual (*Instituto de Socorros a Náufragos*) this complex knowledge is condensed in 7 pages of elementary information. This divulgation of information to the public was already urgent in 1970, when the beach surveillance was reinforced, as well as the training and divulgation to prevent sea accidents (Pereira, 2001). Today, it is still up to the bather's experience the deadly trial and error evaluation of "environmental conditions".

2.3 Hypotheses

Hypotheses are the answers to the starting question that the Problem in study raises, i.e. plausible predictions as result of the literature research. In Oceanography, a "systematic and considered approach" is required for discovery given that the ocean (climate) system "can be characterized by modes that can be thought of as naturally occurring patterns of variability, with each pattern exhibiting unique spatial characteristics but typically vague temporal characteristics": "the knowledge about patterns and processes in the ocean results from the observations of relevant parameters" (Anderson, 2003). And "Surfing is a feeling for the sea, a combination of love, knowledge, respect, fear – instinctive perception gained through repetitive contact" (Wardy, in George, 2001).

"Observation is an essential prerequisite to identifying and understanding the complex patterns and trends of variability in the ocean, complemented by hypothesis-driven studies focusing on cause and effect [with non-linear relations in these systems].
The study of these patterns, identified by experienced scientists, starts in observation, then using intuition (inductive method), ***requires the right questions****, leads to "suggestions of possible interconnexions between unrelated facts, in the complexity and subtle relations of patterns and processes*" (Tomczak, 2002). Intuition from experience is expressed in the words of the "King of Pipeline" (Jenkins, 1991): "One of the things you learn riding the waves consistently is your ability to find a pattern, or a rhythm, in the randomness of the ocean" (Stewart, 2011).

2.3.1 Hypothesis 1: Indicators for Perception of Practice Conditions

H#1: For perception of practice conditions, expert surfers use indicators of sea conditions regarding specifier variables of coastal morphology, bathymetry, breaking waves–currents system, tides, and local winds.

2.3.2 Hypothesis 2: Valuation of Indicators According to Practice Conditions

H#2: Expert surfers value different indicators according to practice conditions: wave heights and type of surfbreak (seabed sedimentary or permanent).

2.3.3 Hypothesis 3: Indicators for Perception of Wave Profile

H#3: Expert surfers use indicators of ramp shape and edge shape for perception of the formation, speed and strength of breaking wave profiles.

2.3.4 Hypothesis 4: Indicators for Perception of Wave Plan

H#4: Expert surfers use indicators of wave wall shape for perception of the formation, speed and strength of breaking wave plan.

3 LITERATURE RESEARCH

There are no previous studies on visual signs for risk assessment on open sea bathing zones. For a classification of Wave Knowledge, we start the compilation with the analysis of the fundamental concepts of Coastal Oceanography, coastal process factors, wave-currents system dynamics, ocean wave elements and properties, wave properties at the coast and surf zone characteristics. We researched coastal engineering studies in wave-currents interaction, for the conjunction occurrences. We attend into nautical scales for wind and sea strength. We narrowed the research by considering the characteristic parameters used in computer modelling for wave forecasting and wave simulation models. We collected the relevant variable specifiers to monitor wind, sea and surf conditions and its evolution in space and time, data available in real-time measurements from systematized sources, like data for the evaluation of surf conditions at the beaches, in the scope of Maritime Safety. From Portuguese Navy's Hydrographic Institute, and Meteorology Institute, we obtained the Characterization of the Climate, and Maritime Agitation, on the Portuguese coast, to know the seasonal sea typical conditions, in typical situations. In order to understand the sediment movement in sandy beaches, we checked coastal erosion processes and seasonal beach profiles.

Determinant clues come from recent Surf Science studies, by surfers, not only on Surf Forecast and "surf spot guides", but now on wave types and profiles, surf break types and ocean bottom topography and bathymetry (scientific investigation held also in Portuguese relevant surf spots), "surfability parameters" (Bicudo, 2007) and breaking waves conditionings (also for Portuguese artificial surf reefs).

Exploratory readings from publications of surfing culture helped our route, due to the complexity of order the phenomena in this dynamic and chaotic environment, with the immense variability of conditions it may present. First we defined the components of a Surf Master (ability, knowledge of surf conditions, experience). Then found examples of intergenerational *retransmission of local surf spot knowledge*. From literature research of surfing master pioneers in extreme surfing, the prospective procedures on their lineup search are picked. We look at sailor's navigation history/ manuals for knowledge of piloting techniques when near unknown seashores. Also, in a method triangulation, to strengthen this exploratory study, using observation in competition, we researched the actions that distinguish surfing champions, the surf lining up (at the primary take-off zone) and the (best) wave catching.

4 MODEL OF INSTRUMENT INTERACTION

This section is dedicated to the sport systematics approach "Model for the Interaction of Instruments" (Peixoto&Ferreira, 1994) (Peixoto, 1997) (Peixoto& Moreira, 1999) (Peixoto, 2000) (Moreira, 2007).

Since our object of study is the sport of surfing, in the perceptual component of the practitioners, it is not possible to use the hierarchy of variables specifiers of natural elements, ranking it for systematization. Therefore we use the term Classification, "the act/ process of classifying each variable in itself" and also "the possible relationship between the [...] variables" (Fernandes, 2000), using grids to order the phenomena, in a methodical way to showcase the different components of this system.

"Analysing sports performance is no more than structuring the different variables/ instruments, clearly and objectively as a resource for effectively improving the technical intervention" (Peixoto, 2000).

The full text of the thesis, available online at the University Repository, contains the classification tables, created for the Wave Knowledge Classification (signals used for evaluating surf conditions), and the Wave Judgement Classification (signals used for evaluating breaking waves components – form, speed and strength). These classifications were the basis of the survey for the experimental methodology of this research.

It also includes the analysis of the motor tasks essential to surfing practice (and to Surf Rescuing), directly related to the wave knowledge: "Surf lineup positioning" and "Wave catching" – identifying the primary wave take-off area, navigating to lineup, choosing the wave, defining the entry point, carrying out the final approach and starting the slide/fall on the wave face. Furthermore, we present a breakdown of the "Take-off technique", and a table of "Classification of Surfing Manoeuvres", organised by level of difficulty and by the part of wave face where it is performed.

5 EXPERIMENTAL METHODOLOGY

This master thesis researches Ocean reading skills. With the goal to present this knowledge organised and quantified, based on information gathered in literature research, indicators were systematized for evaluation of practice conditions and recognizing patterns and trends (*padrões e tendências*, in Portuguese) at the coastal process and on the surf.

For testing this Classification through a research instrument, namely to gather information by inquiring a group representative of the population in study – the best Portuguese surfers –, we created a Questionnaire, designated "Relative valuing, by expert practitioners, of signals in the surf zone for the optimization of wave catching" ("*Valorização relativa, por praticantes peritos, de sinais na zona de surf para a optimização da entrada na onda*", in Portuguese). The design was completed in December 2007, and the implementation took place in January 2008.

5.1 Validity and Guarantee of the Instruments

The questionnaire was subject to validation, through expert opinion test, with the collaboration of Professor Bicudo, also a surfer with 15+ years of experience and teacher of surf forecast for surf coaches.

The theoretical grounding, based on the classification made, followed strict guidelines on information sources due to the pioneering and exploratory character of this research. In the literature review, information from the essential parameters of coastal Oceanography and Meteorology was gathered, such as the ones monitored for the navy institutes, used for modelling surf forecasts, as well the ones referred to in surf modelling studies. As regards journalistic sources (surf magazines), we considered articles resulting from fundamented investigation, such as dictionaries, historical reviews, and biographies. For publications, books about surfing, only used author's considerations after a critical analysis, searching the original sources and writers known for excelling as surfers, especially when they become academics and research on studies in the areas of Oceanography, Sports Training, History, Anthropology, Sociology or articles about technique and strategies for success.

The closed options questionnaires are objective and require less effort from the respondent. Given the length of the questions, it was the best option; it also facilitates the processing and analysis of information by requiring less time. A limitation of the application of this type of questionnaire is that it makes answering easier to an individual who did not know or have difficulty in responding to a particular issue.

5.2 Population Inquired: National Surfing Champions

The study required a sample of top Portuguese expert surfers, that meet this criteria of very relevant verifiable curriculum in surfing: 1) surfing experience (at least 15 years of practice); 2) elite surfer with exceptional results in competition (achievement of national surf champion title in adult category); or 2) to be a surf coaches master (teacher). Since the official competitions began in 1986, the limited universe of the population justifies considering that respondents are sufficient for valid general conclusions.

Men and Women are considered alike; they must meet criteria 1) and 2). A total of 11 elite surfers

were inquired, 2 women included. Actually, those were the only women in Portugal that had more than 15 years of surf experience cumulated with national champion titles, for that PL won almost all the feminine titles (11) and a Guinness World Record for that. Ages range from 32 to 42, practice time is above 20 years (except for 2 subjects), 5 are Physical Education university graduates, 2 authors of master theses on surfing and 1 PhD in Physics. All the surf coach masters and all the women meet the criteria, and several respondents are professional surf coaches.

5.3 Instrument: Questionnaire "Relative Valuing, by Surf Masters, of Signals in the Surf Zone"

The data was retrieved by means of a questionnaire, with a two level "Rating Scale" (options *important/ not important*, or *no opinion*), divided in four parts: Instructions, Identification, Wave judgement skills, Wave knowledge skills:

Part 1) **Presentation** of the project "Proficiency in positioning in the surf zone and wave catching choice of relevant signals from the natural context" and Instructions (1 page);

Part 2) **Personal Data** (1 page): identification, profession, academic/ technical formation in sport, champion titles and years of surf experience, wave size specialization;

Part 3) **Wave Catching motor task**, regarding **Wave Judgement skills** (4 pages, 75 items, 75 marks). Studies the skill of evaluating the breaking wave; it's presented as a classification of indicator signals from breaking waves' formation in the surf zone: points, lines, speeds and strengths from:

1: Wave Profile (**1.1 Ramp shape**: sub subcategories 1.1.1 Slope of wave ramp, 1.1.2 Transition curve; **1.2 Lip shape**: sub subcategories 1.2.1 Lip thickness, 1.2.2 Lip curtain length, 1.2.3 Lip curve/ tube shape, 1.2.4 Lip strength);

2: Wave Plan (**2.1 Wall shape**: sub subcategories 2.1.1 Wave wall height, 2.1.2 Wall slope, 2.1.3 Wall length, 2.1.4 Wall curve, 2.1.5 Angle of swell line peeling, 2.1.6 Wall curl speed; **2.2 Sections shape**: sub subcategories 2.2.1 Wave sections, 2.2.3 Force lines, 2.2.4 Force zones in wave sections).

Part 4) **Surf Lineup Positioning Motor task**, regarding **Wave Knowledge skills** (9 pages, 160 items, 595 marks). Studies the skill of sea reading; it's presented as a classification of indicator signals from sea agitation (combined sea ripples and swell undulation), surf zone bottom configuration and depth, wave-currents system, wind, tides:

1: Swell > Wave interaction from Groundswell and Windswell (Sub categories for Surf Conditions: 1.1 Good; 1.2: Medium; 1.3 Easy; 1.4 Difficult; 1.5 Dangerous);

2: Seabed > Wave interaction (Subcategories for Maritime Geology and Bathymetry on coastal zone: 2.1 Coastline and natural/ artificial obstacles; 2.2 Seabed; 2.3 Surf zone bottom);

3: Currents > Wave interaction (Subcategories for Water circulation cells, or currents types: 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10);

4: Wind > Wave interaction (Subcategories 4.1 Large scale atmospheric circulation; 4.2 Local winds);

5: Tide > Wave interaction (Subcategories 5.1 Tide state; 5.2 Spring Tides; 5.3 Neap Tides; 5.4 Onshore wind Setup and Storm Surge conditions);

6: Atmospheric conditions > Visibility signs.

The 160 questions from wave knowledge survey was the most complex part, since each item had four options, which meant that each item was actually a set of four questions: this was done by allowing independent selection for "Big"/ "Medium"/ "Small wave" sizes (and for Medium waves also divided in "Rocky"/ "Sandy" options) – the scale is clearly included in the Instructions. Some situations do not have options to mark in all wave sizes options (e.g., for the situation Sea Wind – small waves in the Fetch generating location), therefore the total number of marks allowed is less than "number of questions x4". This enables us to study the lining up procedures for reaching the primary take-off zone for these combinations: a) Small/ Medium/ Big wave heights, and b) Defined Peak/ Multiple peaks.

The total questions number was 235 (75+160), with 670 choices to mark (75+595); this high number of indicators inquired reflects the complexity of analysing/ ordering the very dynamic (and in a non-linear system) surf zone practice conditions, and, of course, highlights the expertise needed to understand the concepts and situations inquired.

In order to balance the number of questions, it was designed in digital format (Microsoft Excel), distributed individually by email, and the item selection was possible using the keyboard's arrow keys and space bar. The respondents would save a version that was immediately available for data collection and analysis.

Considering what Bicudo writes about this survey "these descriptors are too detailed, possibly waves can be described with fewer parameters", this reflects the modelling studies of conditions in the coastal zone and more particularly on Simulation of

Waves with software for Artificial surf Reefs (Cardoso, 2007), of which the author was mentor. The inquiry had that goal, so that the surfers were filtered from all the cues presented, as we will see in the following conclusions.

5.4 Data Analysis

In the global analysis of the grid filling of the questionnaire we immediately find partial responses to the hypotheses being studied. From the statistical analysis of the results we find critical items marked unanimously as important, and strong categories are revealed. These main results are presented below.

5.4.1 Hypotheses Verified as True

The propositions that respond to our initial question are verified as true: H#1 respondents mark the most signs systematized – they do attend to all elements of nature in presence; H#2.1 differentiate clearly the relative importance of the visual signs according to the wave height scale – surfers value the same signs differently according to the current surf conditions (it is observed that they consider more details in bigger wave conditions or more diffuse windseas); H#2.2 they need to use more signals at beach breaks than on stable reef breaks – surfers differentiate the importance of items according to wave break type.
Therefore our researching Hypotheses about Wave Knowledge are found true, respectively: H#1. Expert surfers use indicators of sea conditions regarding variable specifiers of coastal morphology, bathymetry, wave-currents system, tides and local winds for perception of practice conditions; H#2. Expert surfers value the different indicators attending to practice situations: H#2.1 according to the surf height; H#2.2 indicators are valued according to surf zone bottom type.

The Hypotheses about Wave Judgement are found true, respectively: H#3. Expert surfers do divide the wave profile evaluation attending the slope, ramp shape for the bottom part of the breaker, and edge thickness/ lip form for the top part; H#4. Surfers evaluate the form of the wall on the wave front line for perception of the breaker plan.

5.4.2 Correct Assumptions – Women and Men are Equally Surf Masters

The assumptions where found correct. The logical premises underlying this problem ("knowledge and evaluation of forces in the surf") were reduced to minimum so as not to interfere with the validity of the results, and do not refer to the research method followed (questionnaire survey) to validate the classifications systematized. Having found in all bibliographic research no gender difference regarding wave knowledge skills, we assumed that expert surfers could be inquired regardless of gender. In fact, princesses surfers where much praised in ancient sport of surfing (Finney & Houston, 1996) (Pukui, 2003) (Hall, 2004), before the "civilization" brought role differentiation of gender in this practice (Gabbard, 2000) there were always proficient women surfers (Hull, 1976) (George, 2001) (Brown, 2002) (Heimann, 2004) (Ford and Brown, 2006) and women have been training competition surf since it is a profession (Lowdon, 1988). While outside the scope of the study, we found no differences in the responses from the men and women inquired: they are expert surfers, Portuguese national champions with 15+ years' experience alike. The results allow us to say that women and men are equally surf masters.

5.5 Main results - Critical Points for Reading the Surf

The responses to the different items were processed in Microsoft Excel, with data first treated by means of descriptive statistical techniques, analysing mainly the percentage of occurrences. On closer examination of the results, we highlighted the critical points to meet in evaluating the surf (items considered unanimously as important) and strong categories (groups of items for each element of the system) from each factor inquired (Waves, Bottom, Currents, Wind, Tides). We considered those items with at least 9 positive responses, from the total of the 11 experts inquired. Therefore the percentages of 82% or higher, in the analysis by item, are presented as unequivocally important, and ordered below. From the various ways to identify visually each signal (variable of each element), surfers marked which they use and which despise. These data were analysed and included in the tables in Appendix.

5.5.1 Swell – Fundamental Signals for Evaluation of Maritime Agitation

The Total Sea present is the result of the superposition of windswell ripples and groundswell undulation ("*o Mar total presente é o conjunto da sobreposição do mar de vento – windswell e ondulação – groundswell*", in the Portuguese original). To assess the **characteristics of the Swell and Total Sea**, expert surfers consider:

1. **Maritime Agitation:** totality of superposition of waves groups comprising ripples and swell (average height, period, direction, exceptional sets);
2. **Swell Height**, extension of wash zone;
3. **Swell Direction** (angle of arrival to coast);
4. **Swell Direction Good/ bad** (distance of rides, good wave formation);
5. **Swell Period** (time between two wave fronts);
6. **Characteristics Associated with the Swell periods** of less than 8-10 sec, 10-14 sec and more than 14 sec (respective heights, length and speed);
7. **Condition of the Swell** (new, maintaining, old), e.g.: period of the waves lowering, power lowering, less frequent series);
8. **Grouping Patterns Characteristics** (number of waves per set, size and formation within the same series [best / biggest waves and how many]).

5.5.2 Swell – Fundamental Signals for Evaluation of Practice Conditions

To assess the **characteristics of the Swell** and to read Practice Conditions, expert surfers consider:

1. Identification of **defined peak, consistent**, allowing positioning by lineup of known marks;
2. Identification of **defined peak, inconsistent**, necessary to adjust at each set;
3. Identification of characteristics of **short period waves** (short wavelength, slow speed, less strength);
4. **Timing of sets** arrival, duration and lulls duration;
5. Typical conditions of windswell: situation of **multiple peaks**, several wave heights and directions;
6. **Difficult Conditions with Small Waves** (local windswell, disordered and irregular waves, with undefined peaks), short period waves, different sizes and directions;
7. **Dangerous Conditions with Bigger Waves** (sea and wind creating strong currents, waves breaking randomly with several patterns present, swell and ripples from various sizes and directions, sets and lulls unpredictable, peak and lineup changing).

5.5.3 Seabed – Fundamental Signals for Evaluation of Type of Surfing Break

To assess the **characteristics of the Coastal Geology and surf zone Batimetry**, and also to define the lineup and references for the lining up technique, expert surfers consider:

1. **Seabed Nature** and **Type of surf break** (pointbreak, reefbreak, beachbreak, mix);
2. **Objects at Sea or shore**, relevant to navigating;
3. **Reference Marks at the Coastline**, for lining up;
4. **Danger Coastal Zones**, currents/rocks/shorebreaks;
5. **Seabed Topography/ Bathymetry/ Slope**, when exposed at low tides, wave sections rising and breaking (shallows) or crest lowering and speeding up (deep channel), distance from surf to shore.

5.5.4 Currents – Fundamental Signals for Localization of Water Circulation Cells

To assess the **characteristics of Maritime Currents** types and to the **localization of the water circulation cells**, expert surfers consider:

1. **Water Volume** in current zone: width and depth;
2. **Zones of Surface Turbulence** (chop), with white foam remaining on lulls;
3. **Speed of Water** moving in the current: surfer's displacement, or white-water or floating objects;
4. **Strength of the Wash** of water moving in the current (height/ speed of white-water);
5. **Location and Speed of Alongshore Currents:** water flowing across the beach in channels between sandbars/ submarine ridges;
6. **Rip Current:** zones of convergence of longitudinal currents, producing a strong wash flow directing offshore, perpendicular to the shoreline;
7. **Wave-currents System:** wave breakers zone over elevated ridges >> alongshore current >> ripcurrents in channels between surf;
8. **Current Zones**, identified by seabed morphology;
9. **Coastaljet Current:** Ripcurrent extending further than the outside: due to piers, deep channel (bay), rocks, junction alongshore currents, rivermouth;
10. **Increased Water Flow in Channel of reduced width**, next to rocks and artificial constructions (jetty structures, piers);
11. **Ripcurrent across the Lineup**;
12. **Riptide Current:** increased water flow due to tide getting low;
13. **Rivermouth:** increased water flow;
14. **Shorebreak:** wave height, frequency, strength;
15. **Wave Surge:** wave wash back to sea – undertow current and backwash waves;
16. **Lulls between sets at shorebreak**;
17. **Current Drift:** according relining up.

5.5.5 Coastal Winds – Fundamental Signals for Evaluation of Sea Surface

To assess the **characteristics of Coastal Winds** and valuation of the sea surface and surf formation, expert surfers consider:

1. **Intensity and Strength of Coastal Wind** (effects at sea/ waves/ at land);
2. **Effects at Waves from Wind:** neutral conditions (windless), favourable (offshore), adverse (onshore);

3. **Local Variation of Sea Breeze:** daytime variation of wind Direction and intensity;
4. **Forecast of Typical Local Winds** for synchronization to the best conditions.

5.5.6 Tides – Fundamental Signs for Evaluation of Water Depth

To assess the **characteristics from Tides** and evaluation of the state of the water depth at the surf zone, expert surfers consider:

1. **Tide Period:** daily cycle of low and high tides: one each 12h e25 min;
2. **Tide Direction:** getting low or high, and influence at ocean water depth;
3. **Tide State and Effects on Breakers** (breaking spot and steepness, lineup);
4. **Tide State better for the Surf Spot**;
5. **Water Depths**, looking at the plan where the peeling wave passes;
6. **Depth Quick Changes** when in Half tide phase (in 2h half of the total water level from tide moves);
7. **Tide Conjunction Effects of Greater Amplitude:** difficult, quickly changing conditions;
8. **Difficult Conditions for Entering/ leaving** the ocean, due to tide state;
9. **Local Influence of Effects for Amplifying Swell Height:** peaks good at low tides, or at other phase;
10. **Forecast of Local Tide Typically Good** for synchronization to the best surf spot conditions.

5.5.7 Atmosphere – Fundamental Signs for Evaluation of Visibility

To assess the **characteristics of factors regarding Visibility**, expert surfers consider:

1. **Poor Visibility: Low Light** (sunrise and sunset); **low contrast** (foggy – sky and ocean on same colours); **backlight from sun** (after midday, at Portuguese West coast);
2. **Low Visibility (Mist or Fog):** increased attention to other signs of waves arrival and passage – surf sound, perception of surf direction and height when swell front line passes, bubbles from ridges, surfacing sediments, perception of currents speeds.

6 CONCLUSIONS

In sport systematization, we look for means to quantify and reduce the complexity by relations between different systems, creating strategies to simplify everything that looked cluttered/ complex (Peixoto and Ferreira, 1994). The most relevant results retrieved from data analysis information, complying to the relationship with the objectives and researched hypotheses, show the fundamental points for the expert surfer's knowledge used to assess the surf conditions, systematized (ordered, classified, then filtered on its importance) in this study. This led us to the definition of this "wave knowledge" skill.

We can now answer our starting question and say: it is possible to systematize the surfer's "wave knowledge" about wave-currents dynamics in the surf zone, by means of a classification of their usage of relevant visual signals from the coastal process when evaluating the surf zone.

Regarding the Wave Knowledge, results show that very experienced surfers evaluate variable specifiers of all elements of the "waves-currents system", considering of greater importance the factors related to identifying the location, type and intensity of maritime currents (except under conditions of small waves), and the swell characteristics (mainly the direction and angle of arrival to coast, height, period). The importance of the characteristics of each element observed varies according to the wave height and for wave breaks types ("multiple peaks"/ "lined-up peaks", roughly corresponding to ocean bottom types sedimentary/ stable). They pay attention to the configuration/ depth of oceanic bottom, and coast profile.

As for the Wave Judgement, for evaluating the quality of the surf, surfers consider the general characteristics of the coastal wind and temporal characteristics of the tides. For assessing the strength of the surf and perception of the take off point of descent, surfers focus on the characteristics of the different sections (plan of the swell line peeling zone, or where the curling wave has its critical zone) and wave face profiles (analysing the slope and thickness; the bottom curve and top edge/ lip form).

6.1 "Wave Knowledge" Skill, Critical Points for Surf Reading

These are the **critical points to consider in surf zone reading and** objectivity in **risk assessment**. For surf conditions evaluation, the fundamental signs from the coastal process, concerning the general characteristics of waves and currents, are:

1. **Identification of the Maritime Currents:** localization, directions and intensities of the water circulation cells in the surf zone (except for small wave conditions, under 1m); mostly to these types of coastal currents (other drifts are negligible):
   1.1. **Ripcurrents** (*agueiro* in Portuguese), zones

of concentrated current return:
1.1.1. **Alongshore currents** in places of longitudinal currents convergence (*correntes longitudinais/ paralelas à costa*, in Portuguese);
1.1.2. **Ripcurrents in deep water channel** (*agueiros de canais profundos*);
1.1.3 **Riptides** (*correntes de maré*);
1.2. **Wave surge and undertow** (*correntes de retorno da onda na rebentação direta na costa*).
2. **Characteristics of coastal geology**:
2.1. **Seabed type, forms and obstacles**;
2.2. **Wave break type** (point, reef, beach, mix);
2.3. **The interaction wave-bottom**.
3. **Coastal wind characteristics** influencing state of sea surface and surf formation (direction, intensity).
4. **Characteristics of the Tide state**.

6.2 "Wave Judgement" Skill Definition, for Wave Formation Evaluation

These are the **critical points to consider in wave judgement**. For wave formation evaluation, the fundamental signs from the coastal process, concerning the **wave profile** (ramp shape and ledge shape, divided where the wave face bends) and **wave plan** (wall shape of the breaking wave), are:

1. **Location of the Primary Peak** and **Wave Form at that Spot** (height, slope, wave wall shape, edge shape);
2. **Swell Line Characteristics**;
3. **Wave Sections Characteristics**;
4. **Wave Profile**, differentiating the top and lower part of the wave incline;
4.1. Ramp slope (lower part of the wave incline)
4.2. Ramp shape, "fat" or "concave"
4.3. Edge thickness (top part of the wave incline)
4.4. Thickness and strength of the falling lip
4.5. Length of the falling lip

6.3 Extreme Caution Situations

A word on extreme danger situations that were described unanimously throughout the investigation that can suddenly arise: any fast rising swell; storm surge or fetch passing; an exceptional set of rogue waves; coastal jet ripcurrents; sudden occurrence of fast moving currents (over 1m/sec) by conjunction of: very angled to coastline swell direction/ riptide/ deep channel/ confluence of alongshore/ tide state/ currents; big wave (over 3m) swells; endless sets (waves breaking continuously without lulls); change in rivermouth flow (such as rain, tide direction change, sudden opening of dam). Tragedy is favoured by actions like facing back to shorebreak, bathing in no surf zones in a beach with surf, going in surf-swimming without full awareness or advice.

6.4 Recommendations

"When we intend to innovate we question the way the situations have been organized. [...] When you try something new, mistakes are made, risks are run, but it is a form of evolution, in the perspective of achieving a solution more suitable or better fit in the different contexts" (Peixoto, 1997). We hope, above all, to contribute to the public information essential to Beach Safety, creating a theory for the training of rescuers, contributing to the scientific area of Sports Training, laying the foundation for educating behaviours that become cultural practices. Application suggestions are available in the thesis full text, ranging from bather safety to training.

Figure 2: The motivation: Portuguese flag, bathers, Joana.

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APPENDIX

The auxiliary documents, the Questionnaire and all data charts are available in Technical University of Lisbon repository, www.repository.utl.pt, from Brogueira, J., Peixoto, C. (2011). *Sistematização do conhecimento dos sinais relevantes na avaliação do mar na zona de rebentação de ondas: Proficiência no posicionamento na zona de surf e na entrada na onda*. Unpublished Master Thesis, Universidade Técnica de Lisboa [UTL], Faculdade de Motricidade Humana, Lisboa.