Affordance-Based Assessment is Neither Subjective nor Objective Outcome Measure

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Abstract

There is increasing awareness of the need to include patient-reported outcome (PRO) instruments in evaluatingthe measurement of clinical outcomes, withan increasing focus placed on the patients'perspective.Scientists have tried to link PROs with objective outcomes, providing unique information formanaging patient care. Traditionally, objective and patientreportedoutcomes (such as the Knee Injury and Osteoarthritis OutcomeScore (KOOS)) are considered two distinct constructs, which cannotserve as a direct proxy for each other.Gibson´s affordances are properties taken with reference to the patient. They are neither objective nor subjective.The present article develops a theoretical framework called entrainment of touch and posturethat advocates the vis viva (living force) as the proper gauge for the dynamical action of a force, and that could explain "possibilities for action or affordance" during outcome measurement.

Index terms— gibson´s affordance; entrainment of touch and posture; affordance-based-assessment; knee synergy.

individual patient (Karlsson, Hirschmann et al. 2015). A critical pre-operative decision concerns the placement of a tibial-femoral tunnel mimicking the native orientation of the ACL attachment (Karlsson, Hirschmann et al. 2015). Surgeons need to consider particular aspects of the local anatomy and, by extension, the biomechanical artifacts introduced during surgery.

Considering the importance of the sensory function of the joint structure, it would seem sensible to minimize the sensory damage of the joint whenever operative treatment is necessary (Johansson, Sjölander et al. 1991). The joints are exploratory sense organs, but they are also performatory motor organs; that is to say, the equipment for feeling is anatomically the same as the equipment for doing (Gibson 1966). Here, we report an alternative approach based on the understanding of knee affordances to guide surgeons in the design/assessment of knee reconstruction strategies.

To our knowledge, this is the first study to use psychological theory to address this surgical assessment concept (Niama Natta, Thienpont et al. 2019). Traditional rating systems to assess clinical outcomes after joint arthroplasty are often based on the surgeon'sobjective ratings, such as range ofmotion and strength, or clinical ratingsof function and pain. However, the patient's perceptions after arthroplasty may differ significantly from those of their clinician. Moreover, surgeonsoften under appreciate the needs and views of their patients (Kinnaman, Farrell et al. 2006). There is, therefore, increasing awareness of the need to include patient-reported outcome (PRO) instruments in the evaluation of surgical procedures. Indeed, these patientcentered assessments of treatment outcomes are becoming today's standard (Rolfson, Eresian Chenok et al. 2016).

Patient-reported outcome metrics (PROMs) can be simply described as a patient's health status selfreport. A 'forgotten joint score,' corresponding to when a patient forgets the artifact in their everyday life, was introduced in PROM as the ultimate goal in joint reconstruction (Behrend, Giesinger et al. 2012). 'Forgotten joint scores' are often observed in patients after surgery (Hamilton, Giesinger et al. 2017). Nevertheless, these ratings do not replace the need to understand the general role of artifacts and affordances in reconstruction surgery. This study aims to identify patient-reported outcome (PRO) instruments in evaluatingthe measurement of clinical outcomes, withan increasing focus placed on the patients'perspective.Scientists have tried to link PROs with objective outcomes, providing unique information formanaging patient care. Traditionally, objective and patientreportedoutcomes (such as the Knee Injury and Osteoarthritis OutcomeScore (KOOS)) are considered two distinct constructs, which cannotserve as a direct proxy for each other.

Gibson´s affordances are properties taken with reference to the patient. They are neither objective nor subjective.The present article develops a theoretical framework called entrainment of touch and posturethat advocates the vis viva (living force) as the proper gauge for the dynamical action of a force, and that could explain ”possibilities for action or affordance” during outcome measurement.

We found that active touch and posture refer to what is ordinarily called touching-variations in skin stimulation caused by surfaces are altered together by motor activity variations. This affordance of ”walk-on-able” is worth noting because it is often neglected that locomotion and its surfaces form an inseparable pair. The assessment process can be viewed in terms of action possibilities provided by the active sets of organs residing that can obtain and utilize information about the tissue environments in which the grafts are to be located.

1 Keywords: gibson´s affordance; entrainment of touch and posture; affordance-based-assessment; knee synergy; instantaneous knee screw (IKS); patientreported outcome (PRO).

2 I.

Anterior Crucial Ligament Reconstruction and its Assessment he anterior cruciate ligament (ACL) is a critical knee joint, bone-to-bone connected, stability ligament that is attached from an anterior location of the proximal tibia to a posterior location of the distal femur. The ACL is highly susceptible to failure during athletic activities and slip-fall events (Howell 1998). The goal of ACL reconstruction surgery is to rebuild the ligament attachments as closely as possible to the native anatomy in order to restore pre-injury knee function and normal proprioception in the affected knee (Behrend, Giesinger et al. 2017). Personalized medicine in surgery allows the customization of insertion sites, graft size, tunnel placement, and graft tension for each T measurable invariants using a (positive) affordancebased assessment strategy for the structural function of the joint during ACL reconstruction. The term ‘affordance’ is conventionally traced to James J. Gibson, and his programmatic approach to perception and action, Ecological Psychology (Gibson, 1979). The notion appears simple at its core, and yet upon closer examination, it has the potential to reveal a radically altered view of the relation between an organism and its environment (Cummins 2009).

The fundamental hypothesis of the ecological approach and this work is that active organisms of the knee that can obtain and utilize information about persisting properties of their tissue environments in which the grafts are to be located will have a definite advantage over organisms that cannot do this.

3 II.

The Affordance of the Knee Gibson demonstrated how animal perception and action is continuous, with interactions with inanimate objects or surfaces (Gibson 1979). The affordances of a product are what it provides, offers, or furnishes to a user. Gibson’s ’system theory’ of perception corresponds to an open system, which is rather different from the view of isolated artifacts (Gibson 1966). The resources encountered by an animal or thinking humans are the affordances of the environment. Affordances are opportunities for action, not causes or stimuli (Reed 1996). The impetus for any knee surgery project can be understood in terms of creating and changing affordances. The design process is the construction of an artifact that offers specific affordances but not certain undesired affordances. An artifact with more positive affordances is considered better, while an artifact with more negative affordances is considered worse.

The ecological approach demonstrates how humans (and other animals) perception and action are continuous with interactions between animate and inanimate physical systems (Kelso 1995). However, the fact that interactions between the inanimate graft and animate patient are continuous precludes the need to identify the patient-reported outcome (PRO) as a distinct category, which can then be incorporated within the larger theory.

4 III. Entrainment of Touch and Posture

Entrainment refers to an individual’s chronobiological, physical, and behavioral relationship with their environment. Specifically, this refers to the coupling of two independent oscillatory systems in such a way that their periods of oscillation become related by virtue of phase alignment (Cummins 2009).Contrasting the established idea of senses, Gibson considered separate anatomical units as perceptual systems (Gibson 1966). In the present case, a joint yields spatial information, a skin-nerve conveys contact information, and in certain dynamic combinations, joint and skinnerve yield synchronization or entrainment specifying information about the layout of external surfaces during locomotion.

Behavioral dynamics in a consistent approach havebeen proposed to account for the dynamics of perception and action (Warren 2006). This approach followed Gibson’s idea that rather than being localized in an internal (or external) structure, control is distributed over the agent-environment system, in the present case, the user-artifact-surface system. Therefore, Warren's behavioral dynamics argues for a one-to-one correspondence between the internal structure IKS (Instantaneous knee screw)(Kim, Araujo et al. 2020), constituted by the internal forces formed by the distal end of the femur and the proximal end of the tibia, and the external structure, represented by the ground reaction forces (GRFs) on foot (Beer 2010).

To test such an ecological approach to perception and action during the stance phase of a gait, we compared previously published experimental data sets (Fregly, Besier et al. 2012) with our predicted datasets) in terms of medial and lateral contact forces. Available data included limb motion capture, fluoroscopy images, GRFs, electromyographical readings determining muscle forces, as well as medial and lateral knee contact forces derived from GRFs. Data were collected from an adult male with a right knee reconstruction (65 kg mass and 1.7 m height).

In this study, the IKS was determined by a linear combination of two separate instantaneous screw axes of the shank (S) and thigh (T) (Figure 1(a)). Let the motions of (S,T) referred to their respective axes, the instantaneous shank axis (ISS) and the instantaneous thigh axis (ITS) respectively (Figure 1(a)); the motion of the shank referred to the same system of coordinates as the thigh, is obtained by the transformation of coordinates. The motion of the shank then takes the form (Figure 1(b)). This follows from the well-known result that a pair of (S, T) have the IKS in common velocity (Ball, 1900). Then, the motion of the shank at the IKS has to be momentarily at rest and stay within the thigh. We can introduce a reference system that moves with the thigh, and we can observe the shank in that system. The criterion for the equilibrium of an arbitrary system of forces at the given knee is that the total virtual work of all forces vanishes (Lanczos 2012). This criterion involves virtual, not actual displacements, and at that instant, the actual motions of the T and S enter into account as the invariant ISS and ITS (Figure 1(a)). Since the virtual displacement, the variation of the IKS, involves a possible but purely mathematical experiment, it can be applied at a certain definite time (even if such a displacement would involve physiologically infinite velocities). As an affordance of the knee for a patient, however, the IKS's have to be measured relative to the patient. They have unity relative to the posture and touch of the patient being considered (Gibson 1979).

Coupling introduces a constraint on the behavior of each limb. The motion of the shank is no longer completely independent of the phase and velocity of the thigh. In relative coordination, there is a tensegrity structure between the intrinsic dynamic structure of each of the two systems and the coupling force that links them. Behavioral dynamics control laws indicate that the entrainment or coordination of the shank and thigh (S, T) follows the same physical laws as the entrainment between the knee and ground (IKS, GRF). In order to tease out the implications of this claim, it will be necessary to introduce and clarify the notions of both affordance and entrainment. Coupling of (S, T) introduces a constraint on the behavior of each limb. The motion of one limb is no longer completely independent of the phase and velocity of the other. This very important characteristic of coupled systems generally has as a consequence that the resulting composite system is effectively of a lower dimension than the aggregate of the components (Cummins 2009). Therefore, the cross-ratio (Semple and Kneebone 1960) of the ordered pair (IKS, GRF) with respect to the ordered pair (S, T) is .

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In particular, if , then (IKS, GRF) divide a pair of harmonically (Courant and Robbins 1941). The fundamental hypothesis of this work is that affordances of the knee create selection pressure on the behavior of individual limbs, as perceived by its invariant, ISS, and ITS; hence is regulated with respect to the affordances of the environment for a given patient. One of most profound is that a pair of invariant (ISS, ITS) can be so selected with reference to the other pair of invariant belonging to the knee system (IKS, GRF) that the IKS nearly coincides with a reciprocal screw of the GRF, as indicated in a magnified inset image in Figure 1(b). The motion of one limb is no longer completely independent of the phase and velocity of the other. The IKS is perceived as an affordance for the entrainment of movement of (S, T).

A perceptual system of the knee can come to equilibrium since twists of amplitudes S and T neutralize. We thus see that the two kinds of action: actual motion at the knee joint (S, T),can be selected with reference to the virtual work function of (IKS, GRF) as also categorized as the performatory and exploratory action during human walking (Gibson 1979). Active organisms of the knee that can obtain and utilize information about persisting properties of their tissue environments in which the grafts are to be located will have a definite advantage over organisms that cannot do this.

When the variations in the ground contact (magnitudes and direction) were shown along with the variations of knee movement in terms of IKS, an invariant was determined uniquely by the two corresponding pairs, see equation (1) (Figure 1(b)).

For a given IKS (when an observer perceives the affordance of the surface) and the location of the center of pressure (COP) on the axis of the GRF is known, then the GRF vector is limited to a plane in the screw system of the first order (Kim, Veloso et al. 2013) (Figure 1(a)). The muscle synergy ? and GRF ? are then compounded into an invariant, limited to the plane of the COP in reciprocity with the IKS. This theorem was originally proposed by Möbius, who showed that forces from six lines could be equilibrated, and also, if five of the lines are given along with a point on the sixth line, then the sixth line is limited to a polar plane (Ball 1900).

Thus, the affordance of the knee has the potential to diagnose pathologies. The last decade has seen a paradigm shift in the measurement of clinical outcomes, with an increasing focus on the user's perspective, PROMs. Many clinicians, though, are less confident in self-reported PROMs, than in 'objective measurements'

(Hamilton, Giesinger et al. 2017). Recent studies identified several sensations, activities, and psychological factors such as feelings of instability and knee-related fears that make the patients aware of their artificial knee joint (Loth, Liebensteiner et al. 2018). They concluded that joint awareness might work as an overarching parameter. This is aligned with Gibson's statement that an affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy (Gibson 1979). Affordances have to be designed in relation to the uniqueness of each patient, and thus posture and movement need to be measured in terms of a specific patient-environment system, not in patient-centered terms. [1]

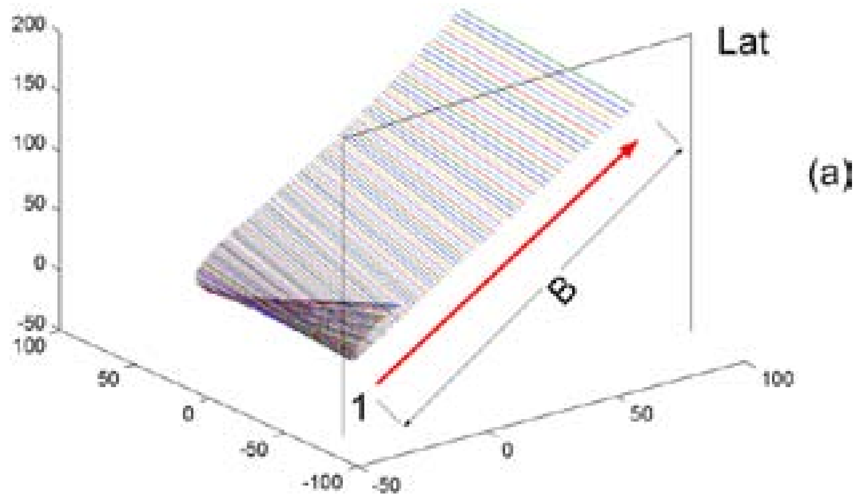

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Figure 1: Figure 1 (

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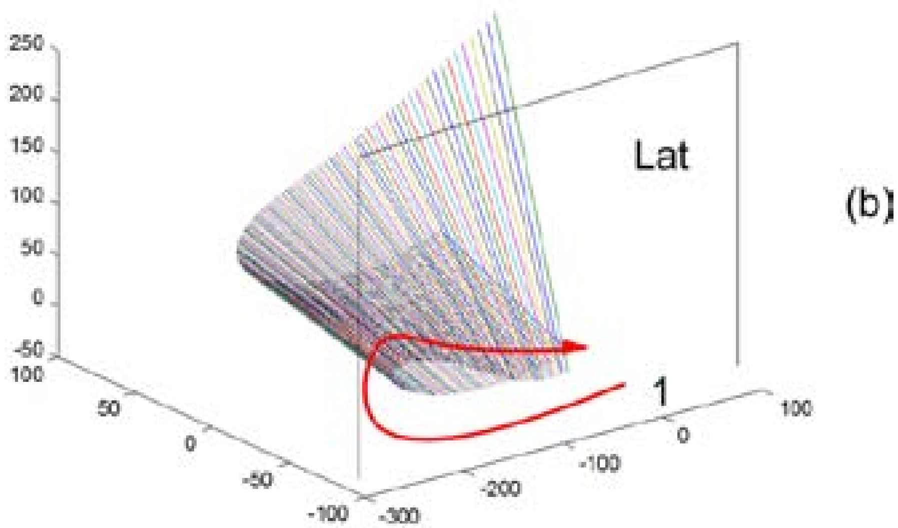

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Figure 2: Figure 1 (

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