

Digital Methods in Intangible Cultural Heritage Research: A Case Study in Tango Argentino

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With this paper we present the ongoing research project “Tango Danceability of Music in European Perspective” and the transdisciplinary research design it is built upon. Three main aspects of *tango argentino* are in focus – the music, the dance, and the people – in order to understand what is considered *danceable* in tango music. The study of all three parts involves computer-aided analysis approaches, and the results are examined within ethnochoreological and ethnomusicological frameworks. Two approaches are illustrated in detail to show initial results of the research model. Network analysis based on the collection of online tango event data and quantitative evaluation of data gathered by an online survey showed significant results, corroborating the hypothesis of gatekeeping effects in the shaping of musical preferences. The experiment design includes incorporation of motion capture technology into dance research. We demonstrate certain advantages of transdisciplinary approaches in the study of Intangible Cultural Heritage, in contrast to conventional studies based on methods from just one academic discipline.

CCS Concepts: • **General and reference** → **Empirical studies**; Design; • **Social and professional topics** → **Cultural characteristics**; *Geographic characteristics*; • **Applied computing** → **Performing arts**;

Additional Key Words and Phrases: *tango argentino*, choreomusicology, social network, cosmopolitanism, scene formation, dance, music, motion capture

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1 INTRODUCTION

Tango argentino, added to the UNESCO list of intangible cultural heritage in 2009, is one of the most well-known music and dance forms internationally. It is a heterogenous performing arts genre, hard to define and contain¹. Many styles in music and dance coexist under the umbrella term *tango argentino*. On one end of the spectrum, there are staged and choreographed dance performances, and complex tango art music, composed for concert audiences. On the other, there is social tango dancing, based on improvisation, carried out to tango music that is

¹For a look into the controversy surrounding the declaration as UNESCO intangible heritage see [50].

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composed particularly to suit the needs and tastes of social tango dancers. This study focuses entirely on the socially danced form of *tango argentino*, the corresponding music, and the social network structures that bring people together as they practice, continue and form the genre as a cosmopolitan phenomenon². With this paper we introduce the transdisciplinary research project “Tango Danceability of Music in European Perspective”.

Tango argentino, as many other performing arts genres in the realm of intangible cultural heritage, is commonly studied by ethnochoreologists – focusing on dance elements – and ethnomusicologists, focusing on the music. Within ethnochoreology and ethnomusicology, primary research is mostly done through three main activities: the reflection and application of general or topic specific theories, individual fieldwork, and, analysis of the gained material. The main aim of many ethnochoreological and ethnomusicological research projects is to gain insider information and first-hand experience, leading to knowledge from a culture–relativistic perspective. In the 21st century, exploration of digital media, in particular the World Wide Web, has become accepted as a research approach, to add to other, long established techniques³. However, the use of digital research methods for ethnomusicological fieldwork is still uncommon and practiced by few researchers⁴. Further, research in digital media and quantitative methods for the exploration of performing or visual arts sometimes lacks expert knowledge among scientists, either in the shaping of significant research questions, or in the interpretation of the results.

This four year research project combines methods and approaches from both fields and incorporates them into an transdisciplinary research design. The project focuses on three areas: tango music, tango dance, and tango people and their interrelations. Each of the three is looked at separately, with appropriate methods and analytical tools, borrowing from related disciplines such as sociology and communication science. For this paper, we focus on research elements that are prominently supported by digital methods, particularly a social network analysis based on quantitative data, and movement analysis captured by motion capture technology.

The particular innovation occurs not in these digital methods themselves, which have been in use for some time, but in the adaptation for ethnochoreological and ethnomusicological research questions, and the combination of these methods into a holistic research initiative. The aim of this project is mainly to gain enriched information about *tango argentino*. But beyond that, preliminary results presented here show that this transdisciplinary approach, in which researchers from all disciplines involved constantly exchange information and develop analysis tools, approaches and interpretations through continuous feedback in both directions, enables researchers to surpass the knowledge that could be gathered inside the boundaries of one discipline only. We hope that it will serve as an example for future projects in the field of intangible cultural heritage.

2 RESEARCH TOPIC: TANGO ARGENTINO

First, a short introduction will be given into the genre *tango argentino*. This includes the tango’s development in the 20th century, its manifestation today as an international practice, the social network structure of the cosmopolitan tango scene, and finally an overview over musical and choreological elements and the connections between music and dance.

2.1 History and Presence

Tango argentino is a performing arts genre, that involves music, dance, and lyrics. The genre developed around the turn of the 20th century in the area of the Rio de la Plata, mainly in the capitals of Argentina (Buenos Aires) and Uruguay (Montevideo). The structure of the area’s population changed drastically within a short period of

²We are aware that *tango argentino* practice in, for instance, Buenos Aires, is embedded into the local and national culture in a different way than in cosmopolitan *tango argentino* practice elsewhere.

³See for instance Wood’s [2008] elaborations on “e-fieldwork” in ethnomusicology, its advantages and challenges, as well as [39].

⁴See mission statement of the International Workshop on Folk Music Analysis (<http://www.folkmusicanalysis.org/>)

time through a massive economic migration from Europe [44]. The convergence of people from diverse regions and cultural backgrounds, with differing languages as well as music and dance styles, was the basis for the development of this new popular music and dance genre. *Tango argentino*, as it soon came to be called, is a mixture of European, prominently Italian, performing arts traditions, combined with musical elements from South American and African traditions [43, 55].

Soon after it became established, *tango argentino* spread outside of the Rio de la Plata into neighboring South American countries, as well as to Northern America and Europe, and further to North African and Asian countries. In Europe, the new vogue to listen and dance to *tango argentino* spread quickly to most capitals and urban centers via Paris in the 2nd decade of the 20th century (e.g. [28, 30]). Wherever the tango went, it often adapted to local musics and languages, or even transformed completely into other tango genres like the Finish or English (ballroom) tango. It also came to be practiced in its exported form from Argentina and Uruguay by a growing number of urban people across the continents⁵.

In Argentina, the golden age (*época de oro*) of tango took place in the 1930s and 1940s. Musical compositions, performers and dance styles of this period continue to be considered the yardstick against which all subsequent innovations and developments are measured. In the decades following the golden era, the tango has seen times of decline and revival, innovation and reconstruction, both in Argentina, Uruguay and across the continents. Many changes came into being through the continuous reciprocal exchange of people and ideas between Argentina and Europe [24].

Through the 20th century, *tango argentino* has developed from a regional performing art form toward an internationally practiced genre, located in urban centers around the globe. *Tango argentino* can be practiced by everybody, regardless of birthplace and cultural background, yet the practice of *tango argentino* can only thrive under certain circumstances. A politically and socially supported tolerance and openness towards music and dance practice is required, as well as the general acceptance of public physical contact between men and women. In addition, *tangueros* and *tangueras* need to have enough economic and social stability to allow them to take classes, go to dance and music events, travel to festivals, and spend their free time intensely practicing this hobby. While the following analyses and descriptions are true for most international tango scenes, the focus here – as in the project – is specifically on European circumstances.

2.2 Tango Scene Structure

A local *tango argentino* dance scene is comprised of fifty to several hundred members, who meet on a regular basis. This core population is supplemented by more irregular and variable followers. Scene members meet each other and connect at diverse events, ranging from classes held by local or traveling teachers, to regular *prácticas* (self-organized practice), to *milongas* (tango dance evenings) to tango music concerts. Tango scenes are hierarchic, the status of a member being determined by dance skill as well as frequency and duration of involvement in the scene⁶. Social networks can be based on a common interest, purpose or practice, including performing arts [47], and thus tango scenes can be understood as social networks. Within a tango social network, obvious gatekeeping effects occur [20]. In each local scene, prominent scene members (male and female), act as gatekeepers. These individuals travel to festivals or elite dance meetings (*encuentros* or marathons) in other cities or countries, bring back fashions and disseminate dance styles they have learned abroad. They can also embrace organizational activities, like inviting guest teachers and musicians, arranging events, or collecting and playing music as tango DJs. The role of a tango DJ is particularly important and influential, as the music at most dance events (*milongas*)

⁵For a thorough introduction to how *tango argentino* was established as an art form in the 20th century outside of Argentina (based on the example of Japan), see [19] and [24].

⁶For a valuable analysis of the formation of scenes see [26, 183–189].

is taken from recorded sources and the selection and order of the played tango pieces is up to the tango DJ's personal musical preferences⁷.

All local scenes are connected into a bigger, international scene in a variety of ways. First, travel activities by elite and regular members connect scenes through individual encounters, leading to international personal and professional relationships. Second, social media connections between members strengthen the exchange and flow of information. Members on all hierarchic levels have personal contacts to other scene members via social media. In addition, blogs, newsgroups and virtual community pages help share and distribute information within the network.

By means of these two main factors – travel and social media – local scenes form an international tango scene, a group structure that Turino would term a *cosmopolitan cultural cohort* [56].

Shifts and trends in music and dance in this cultural cohort or international social network is driven by innovative forces like regional inventiveness, teacher initiative, commercial interest, as well as by normative powers, like the perceived authenticity of the Buenos Aires scene and the uniform norms communicated in exchange between scenes via travel, digital and social media [51]. Trends and topics of the last years include limits of the music selection being played at *milongas*, the dress code expected from dancers at events, queer tango dancing, and the development of particular tango movement repertoire considered appropriate in specific environments.

Just as any cultural formation, the international *tango argentino* dance culture is not necessarily homogeneous in its values, habits and opinions. As noted above, there is not one fully agreed norm, but rather many diverse *tango argentino* dancing styles. This is caused by the vast number of tango teachers with individual approaches, tastes in music and movement, and the constant change in trends and fashions. Nevertheless, certain stylistic features are more prominent than others and some movement terminology is generally agreed upon while others can be found in niches only. This variety of styles and preferences gives rise to some fragmentation of the international, and to a certain extent, the local scenes. Dance styles and music choices are partly politicized by rivaling groups, each arguing that their own way to dance is the only correct, or 'authentic' *tango argentino*.

2.3 Music, Dance and their Relations

Tango argentino is an improvised couple dance. The improvisation is based on a particular, limited movement repertoire and set rules of basic body position, stride and turning, for both leader and follower. Movements are executed for communication, traveling, turning, and also embellishing. Because of the complexity and concurrence of all of these movement types, learning to dance *tango argentino* is a long and intense process.

Music for social tango dancing is mostly and widely taken from the canon of tango recordings of the *época de oro*. Such classical tango compositions make use of European functional harmony. Basic rhythmical and temporal elements are based predominantly on even meters (mostly $\frac{4}{4}$), alternating parts (A and B), little tempo variation, an even phrase structure, repetitions or variations of phrases, and an absolute tempo of about 120 bpm⁸.

Several of these musical parameters are directly linked to movement concepts. For instance, the tempo and steady beat, with emphasis on the first and third beat of each bar, are connected to even and consistent steps that are carried out on the first and third beat. This leads to a steady, basic walking pace of approximately 60 bpm. Another example of music and movement connections can be found on a music structural level. It is believed that the fixed structure of phrases and repetitions opens up the possibilities of embodied anticipation for the dancer: improvisation is easier and more connected with the music if the dancer can rely on a familiar, stable frame.

⁷In a related research project we focus on the history and presence of tango DJing in general, this particular subject is therefore excluded from this paper.

⁸For a much more detailed and thorough analysis see [2, 35, 42].

The dancer may not experience the musical structure in an analytic and rationalized way, but on an embodied, subliminal level.

Connections between tango dance and music, and the social and musical criteria that make music ‘tango-danceable’, are the subjects of ongoing discussions within tango dance and music scenes, especially among scene experts⁹ concerned with the quality of tango music. The corresponding debate is exacerbated not only by personal opinions and tastes, as well as pressures for innovation and standardization, but also by rivalry in business and competition in interpretation authority¹⁰.

It is obvious that tango music and dance have had parallel developments and influenced each other over the course of the 20th century, both being constantly changing entities. Some structural connections between particular tango dance music styles can be traced back to certain historical periods in the evolution of *tango argentino*, for instance the development of *tango nuevo*, with its main protagonist Astor Piazzolla, and the staged tango dance style (*tango escenario*), both forms having become popular together in the 1980s and 1990s outside of Argentina, mainly through traveling tango stage shows [43].

In present day social tango dancing, several styles coexist, each with a specific movement repertoire. All tango dance styles share a strong relation between movement and sound, on various structural levels, both in movement and sound organization. So far, this complex connection has never been researched with methods other than musical analysis [1, 35] or descriptive renditions from personal experience.

3 TRANSDISCIPLINARY RESEARCH DESIGN

Bridging the gap between academic traditions remains challenging due to differences in approaches, methodology, language, and goals. The research design for this project entails three stages, which overlap in time and content, and integrate elements of diverse academic traditions. First, basic information about *tango argentino*, as summarized in section 2, is gained through long-established methods in ethnomusicology and ethnochoreology: fieldwork, participant observation, thick description, study of primary and secondary sources, expert interviews, and music transcription. The approach is broadened by quantitative methods of data gathering (network analysis, online survey, optical motion capture). Second, the necessary data analysis is yet again a combination of qualitative and quantitative (statistical) methods, based on a constant negotiation and adaptation of approaches in relation to provisional results. Third, the interpretation of final results makes use of intellectual capacities and academic traditions from both areas.

3.1 Network Analysis

We have designed an analytical process that is able to capture relevant quantitative properties of the *tango argentino* scene structure as expressed on the World Wide Web through public notifications and advertisements.

We started from an initial seed list of known *tango argentino* event web pages. We compiled a normalized list of *tango argentino* events by crawling the relevant portions of the seed web pages and creating event instances based on web address, name, edition and date of events. We then crawled the individual event web pages specified on the link pages. The found event information about location and performances was then attached to event instances. In cases where the individual pages are no longer online, we used the Internet Archive (<http://www.archive.org>) to retrieve previous page versions. The process yielded a normalized data structure containing events series, event instances and participating dance and music artists (compare Figure 1).

⁹A scene expert in this study is defined as an individual with close and long connections to the local and possibly international tango scene. This includes the authors Kienreich and Stepputat who are active *tango argentino* scene members for more than a decade and have gathered additional insight from other experts through participant observation.

¹⁰Also see [46, 136–137].

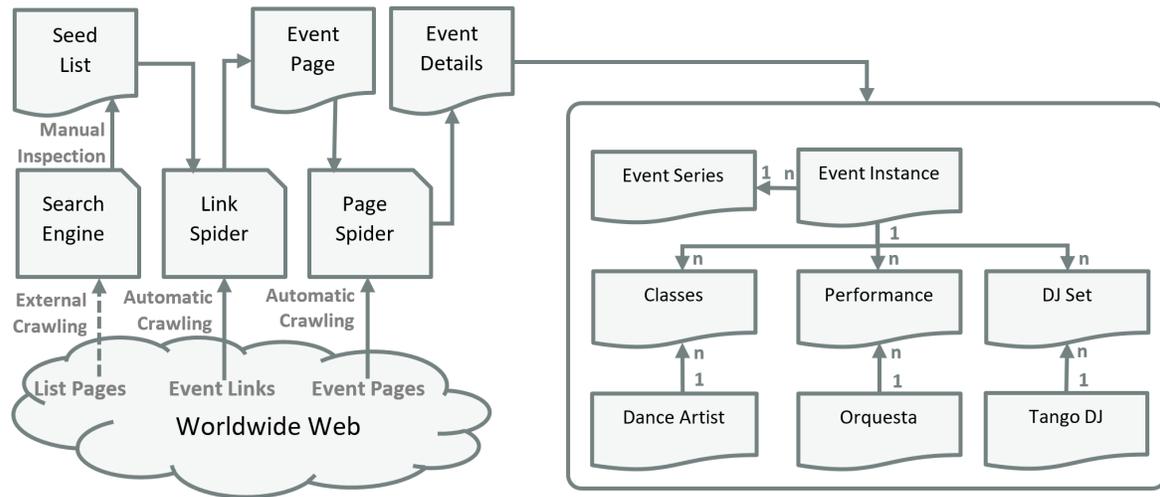


Fig. 1. Online event analytics: Process (left) and resulting Data Structure (right).

We compiled the initial list of seed web pages manually based on expert knowledge and utilizing search engines. Automatic crawling of seed and event web pages will be enabled with web crawling frameworks like Scrapy (<http://scrapy.org>) and entity recognition frameworks like Apache Stanbol (<http://stanbol.apache.org>). In our first experiments, we have manually created a ground truth data set to enable validation of automatic methods. In August 2015, we compiled 254 event instances within a time range of 2012 to 2015 and a geospatial range of 92 locations in Europe. We were able to attribute 1545 teaching performances, 1163 tango DJ performances and 139 live music performances to these events. We only considered events that are open to the public, as for instance *tango argentino* festivals or marathons, and we disregarded *encuentros*, which are often not publicly advertised. Expert interviews and manual research of random samples confirmed that the data set is exhaustive within the given time and geospatial range.

Preliminary Results. Our analysis of the manually created ground truth data set provides several indicators that support the image of a hierarchically organized *tango argentino* scene significantly shaped by gatekeeping effects. Figure 2 shows a typical power law distribution for the total number of tango DJ performances per tango DJ. The top three tango DJs in the considered time period are “La Rubia” Analía Del Giglio (24 performances), “Super Sabino” Sabino Cirulli (24 performances) and Marcelo Rojas (19 performances). In comparison, the average tango DJ performed just 2 times. A detailed analysis of performance locations reveals a regional pattern in which Marcelo Rojas performs mostly in Western Europe, Sabino Cirulli performs mostly in Southern Europe and Analía Del Giglio performs mostly in Eastern Europe. We note that even the top tango DJ performers do not significantly market themselves to the general *tango argentino* scene. We therefore interpret the concentration on a small number of top performers as an indicator of the gatekeeping role of the organizer elite. Similar distributions found in dance and music performances and total event size support this interpretation.

The analysis also yielded quantitative validation of other phenomena that *tango argentino* scene experts have been discussing on a qualitative level for some time. Figure 2 shows an approximately linear increase in the number of festivals during the observation period, but a much stronger, nonlinear increase in the number of DJ performances at festivals. This observation supports the frequently voiced hypothesis that the role of the tango

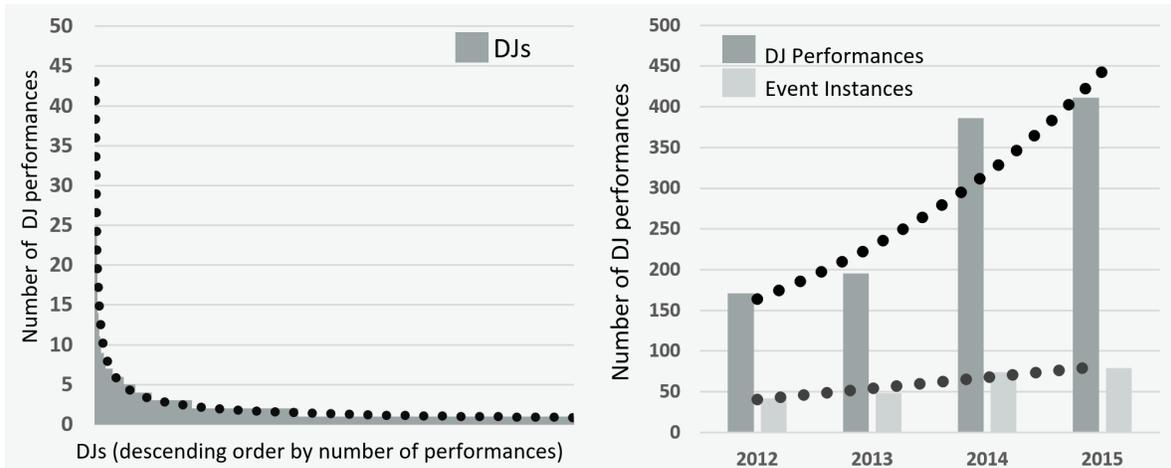


Fig. 2. Quantitative results for 580 tango DJs. Power law distribution of DJ performances (*left*) and increasing importance of the role of DJs (*right*).

DJ has gained importance in the scene discourse, to the point where event organizers actively seek to increase number and variety of tango DJ performances.

We have also conducted advanced graph analytics using the Gephi tool [6] on a network obtained by interpreting the co-occurrence of DJs at events as a connectivity measure in an undirected graph. The network consisted of 584 nodes representing DJs and of 8369 edges representing DJ co-performances. It is characterized by an average degree of over 11.7, a diameter of 8, an average path length of 3.47, and a density of 0.022. Betweenness Centrality, which measures the extent to which a vertex lies on paths between other vertices [9], is highest for the three aforementioned DJs, Marcelo Rojas (27984), Analía Del Giglio (22821) and Sabino Cirulli (12502). We verified that these DJs also are the center of the community by computing modularity clusters [8]. Total modularity is 0.657 and the modularity clusters support the gatekeeping hypothesis (compare Figure 2 *left*).

Network analysis offers a wealth of further research opportunities from an ethnomusicological point of view. For instance, we find that DJ CyberChris is ranked eight on Betweenness Centrality (6499) while he is not even within the top 100 in terms of total performances. Visual inspection after a Fruchtermann-Rheingold layout [22] reveals that this DJ is the only connection of a sub-network of other DJs to the rest of the network. We were also able to identify DJs like Pierre M (compare Figure 3), who has participated in at least three distinct sub-communities and acts as a link between at least two of the top DJs. At this point, further ethnomusicological research, including fieldwork at the respective subnetwork events and qualitative interviews with the respective individuals, should commence.

3.2 Quantitative Data Acquisition and Evaluation

We constructed an online survey to collect evidence on how tango dancers perceive and rank tango music. After conducting a pilot phase of the survey in January 2016 and adjusting the survey setup based on results, we collected actual survey data between February and August 2016. We now have 6589 ratings, submitted during 182 distinct sessions, for a set of 80 musical pieces available for analysis and interpretation. The data set is available online for academic use (<http://www.dancetangomusic.com>).

3.2.1 Design.

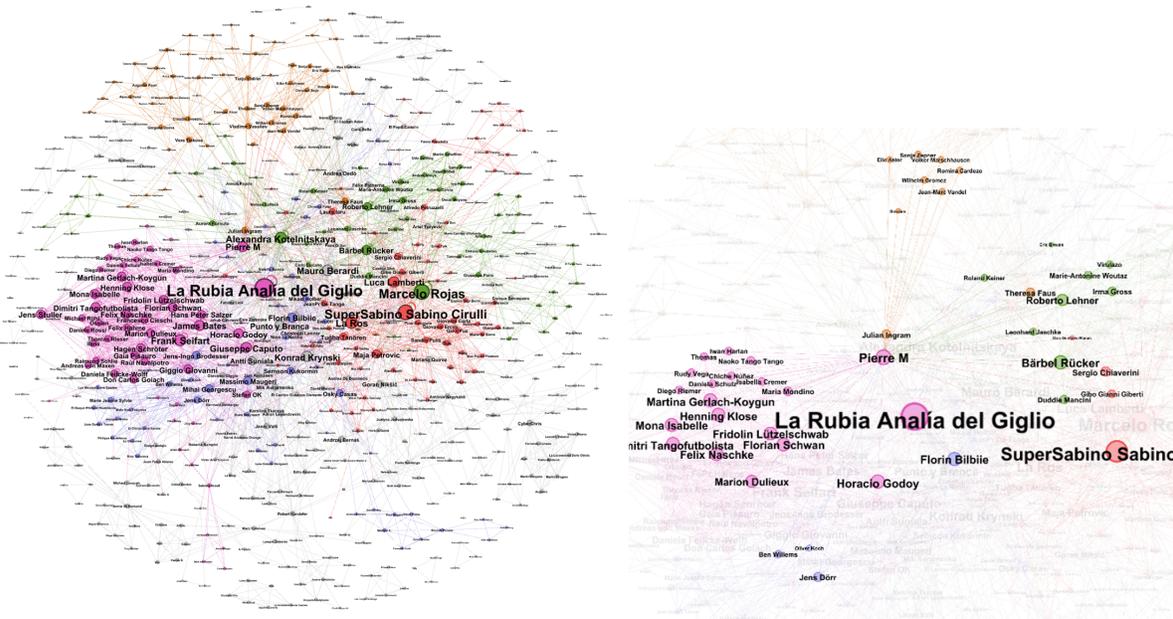


Fig. 3. Social network analysis of DJ network by co-performances. Global network view (left). Gatekeeper for local sub-network (right).

Dissemination. We placed the survey in the web portal of the Dance Tango Music project (<http://www.dancetangomusic.com>). We then distributed a call for participation through more than 20 relevant social media groups identified by scene experts. More than 100 key scene individuals were invited by personal message to participate and further distribute the call. The publication of the call for participation initiated discussions in several expert forums. Many participants agreed that the research topic was worth studying. However, several scene experts expressed reservations about any methodology being able to capture such a complex topic beyond purely subjective impressions. Most survey participation occurred during the first week of the survey period.

Presentation. In the introductory text¹¹ shown to the participants, we stated our intention to narrow down which elements in the music are relevant for a musical piece to be considered ‘tango danceable’. We described the purpose of the survey as collecting personal opinions on the danceability of a wide variety of music to which people dance *tango argentino* today. We further urged participants to express their personal opinion, as opposed to some perceived general knowledge or norm, at several points throughout the survey. We explicitly addressed participants as collaborators in an academic enterprise to research musical factors.

Personal Data. After the introductory text, we asked participants a number of personal questions, the answers to which should serve to contextualize the actual music ratings of participants. These questions included *U1 Gender*, *U2 Age*, *U3 Tango Dance Experience*, *U4 Tango Dance Frequency*, *U5 Tango Musician or Singer*, *U6 Tango Dance Teacher*, *U7 Tango Dj* and *U8 Experience in playing an Instrument or Singing* as ordinal scale variables. They also included a number of binary variables for the groups *I like to dance at (D1-D6)* and *I like to dance to*

¹¹All information is presented in English, as it is the internationally accepted language in Europe and serves as a *lingua franca* within the tango community.

Table 1. Music used in the survey

| Style | Orquesta | Pieces |
|--------------|-----------------|--------|
| Golden Age | Di Sarli | 5 |
| Golden Age | Rodríguez | 5 |
| Golden Age | D'Arienzo | 5 |
| Golden Age | Biagi | 5 |
| Golden Age | Pugliese | 5 |
| Golden Age | Canaro | 5 |
| Golden Age | Troilo | 5 |
| Golden Age | Tanturi | 5 |
| Contemporary | Andariega | 5 |
| Contemporary | Almagro | 5 |
| Contemporary | La Vidú | 5 |
| Contemporary | Sabor a Tango | 5 |
| Non-Tango | Various Artists | 20 |
| Total | | 80 |

(M1-M5), which referred to the preferred dance event type and music style. We also provided text variables for *Current Tango Area*, *Other Dance or Physical Training Experience*, *Favorite DJs*, *Favorite Teachers* and *Favorite Orquestas*. We semi-automatically encoded variable content using semantic annotation methods during survey evaluation. For instance, the encoding of *Current Tango Area* yielded 79 distinct areas and left no meaningful text unused. We aggregated regions into 25 countries denoted as binary variables C0 to C24. Only questions U2 Age and U1 Gender were mandatory.

Music Selection. After providing personal data, participants could choose their musical preference from three different styles (compare Table 1). The first style is labeled Golden Age (*época de oro*), and included 40 *tango argentino* pieces in eight groups of five pieces. Each group contained only pieces from a single well-known *época de oro tango argentino* orchestra (*orquesta típica*). We labeled the second style “Contemporary Tango” and included 20 contemporary tango pieces in four groups of five pieces. Each group contained only pieces from a single well-known contemporary tango orchestra. We labeled the third style “Non-Tango Music” and included 20 pieces of music, which have not been classified as *tango argentino* by the composer or interpreter, but are sometimes played for tango dancing at *milongas*.

Participants could pick one of the three styles, but we presented them with nondescript pieces in random order within each style. We displayed the number of pieces already rated next to each style and urged participants to rate all pieces in all styles. Each piece was presented using an embedded media player, which played a prepared, representative section of the piece with a duration of approximately 30 seconds. For Golden Age Tango and Contemporary Tango, we selected the sections to include the transition from the second musical theme (B) to the repetition of the first theme (A). For Non-Tango Music, which mostly did not exhibit this type of structure, we selected a representative section starting with the transition from the refrain back to the verse, which musically corresponds somewhat with the section selected in tango music. Two reasons influenced the choice of section. First, we wanted to include both main musical themes (part A and B, refrain and verse respectively) to give a thorough impression of the piece. Second, by choosing a section from a later point in the piece, we could ensure that the full musical depth in instrumentation and volume was reached.

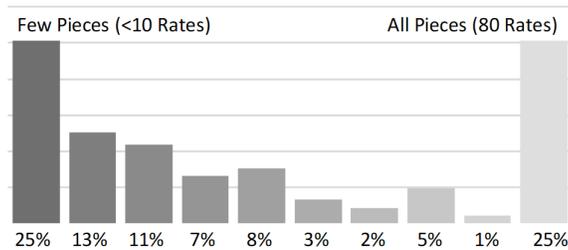


Fig. 4. Number of ratings per distinct session

Rating Pieces. On entering the rating section of one randomly selected piece of the chosen style, the embedded media player automatically started playing the prepared section of the piece. We presented participants with a total of five variables, each of which could be rated on a four point Likert scale, and a text variable for arbitrary input. The variables included:

- Q1 – I know this piece (in this version)** This variable ranged from *Not at all* (0) to *Very well* (3) and captured the familiarity of the participant with the piece.
- Q2 – In general I like this piece** This variable ranged from *Not at all* (0) to *Very Much* (3) and captured the general attitude of the participant towards a piece.
- Q3 – I (would) enjoy to dance tango to this piece** This variable ranged from *Not at all* (0) to *Very Much* (3) and captured the personal dance attitude of participants towards a piece.
- Q4 – For me, the piece is / would be challenging to dance to** This variable ranged from *Not at all* (0) to *Very Much* (3) and captured the perceived complexity and effort in dancing a piece.
- Q5 – In general, I think the piece is tango-danceable** This variable ranged from *Not at all* (0) to *Very Much so* (3) and captured the general dance attitude of participants towards a piece.

We explicitly asked for knowledge about the specific version in *Q1* because dozens of very different versions exist for many Golden Age Tango pieces (and to a lesser degree, for Contemporary and Non-Tango pieces). The formulation of all questions intentionally encouraged a completely subjective answer. We also differentiated between aesthetic attractiveness of a piece (*Q2*), subjective danceability (*Q3*) and perceived objective danceability (*Q5*).

3.2.2 Preliminary Results. We received 6589 ratings submitted during 182 distinct sessions. 25% of distinct sessions rated a very small number of pieces (less than 10 out of 80), which could be interpreted as participants quickly losing interest or not seriously contributing to the survey. Less than 10% of answers for each rating (*Q1* to *Q5*) were not provided (and are not considered in analysis), and 75% of distinct sessions contributed more than 10 ratings (compare Figure 4).

The two variables *U1 Gender* and *U2 Age* were the only mandatory variables in the personal section of the survey, and the vast majority of participants volunteered answers to the variable *U3 Tango Dance Experience*. The slight majority of participants of female gender accords well with expert observation of scene structure. The relation between age and dance experience also paints a picture in accordance with expert observations, with a core of experienced dancers well above the age of 50 and a smaller but still detectable group of younger beginner dancers (compare Table 2).

We requested regional information of participants through the free text variable *Current Tango Area* and encoded results into 25 binary variables expressing if a participant had named one or more regions within a certain country. We included a variable *C24 Europe* which encoded all text not referring to a single country, but

Table 2. Gender, age and dance experience of participants

| (a) Gender | | | | (b) Age and dance experience | | | | | |
|------------|---------|--|-------|------------------------------|-------|-------|-------|-------|--------|
| Gender | Ratings | | Part | Dance Experience (years) | | | | | |
| | | | | 1-3 | 4-10 | >10 | n.a. | total | |
| Female | 3879 | | 58.9% | <20 | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% |
| Male | 2694 | | 40.9% | 20-30 | 1.7% | 2.7% | 0.5% | 0.0% | 4.9% |
| Other | 16 | | 0.2% | 30-40 | 2.6% | 7.5% | 4.5% | 0.0% | 14.5% |
| Total | 6589 | | | 40-50 | 5.4% | 5.3% | 8.7% | 0.6% | 20.1% |
| | | | | 50-60 | 4.4% | 13.1% | 17.4% | 1.2% | 36.2% |
| | | | | >60 | 1.5% | 7.3% | 15.4% | 0.0% | 24.2% |
| | | | | total | 15.7% | 35.9% | 46.5% | 1.9% | 100.0% |

Table 3. Regional preference of participants

| (a) All countries | | | (b) European countries | | | (c) Non-European Countries | | |
|----------------------|------|--------|------------------------------|------|-------|----------------------------------|------|------|
| Ratings per country | | | Ratings (european countries) | | | Ratings (non-european countries) | | |
| Country | abs. | % | Country | abs. | % | Country | abs. | % |
| C0 Germany | 2053 | 31.68% | C0 Germany | 2053 | 31.7% | C3 USA | 521 | 8.0% |
| C13 Austria | 955 | 14.74% | C13 Austria | 955 | 14.7% | C2 Malaysia | 141 | 2.2% |
| C3 USA | 521 | 8.04% | C6 UK | 410 | 6.3% | C8 Argentina | 89 | 1.4% |
| C6 UK | 410 | 6.33% | C14 Italy | 311 | 4.8% | C9 South Africa | 80 | 1.2% |
| C14 Italy | 311 | 4.80% | C11 Switzerland | 306 | 4.7% | C7 Thailand | 78 | 1.2% |
| C11 Switzerland | 306 | 4.72% | C24 Europe | 283 | 4.4% | C16 Mali | 1 | 0.0% |
| C24 Europe | 283 | 4.37% | C21 Turkey | 261 | 4.0% | | | |
| C21 Turkey | 261 | 4.03% | C10 Slovenia | 217 | 3.3% | | | |
| C10 Slovenia | 217 | 3.35% | C12 Belgium | 179 | 2.8% | | | |
| C12 Belgium | 179 | 2.76% | C1 France | 160 | 2.5% | | | |
| C1 France | 160 | 2.47% | | | | | | |
| C2 Malaysia | 141 | 2.18% | | | | | | |
| Other (13 Countries) | 683 | 10.54% | | | | | | |

to Europe as a whole, as for instance "south European festivals". Participants preferring regions in European countries provided 86% of all ratings and a large number of ratings referred Germany and Austria (compare Table 3).

Table 4. Regional bias compared to network analysis study results

| (a) Country coverage | | | | (b) Country rank | | |
|--|-----------|---------|------------|--|------------|--------------|
| Country coverage: Ratings vs. Performances | | | | Country rank: Ratings vs. Performances | | |
| | % Ratings | % Perf. | Difference | Ratings | Rank Diff. | Performances |
| C0 Germany | 31.7% | 9.1% | -22.6% | C0 Germany | 1 | Italy |
| C13 Austria | 14.7% | 4.2% | -10.6% | C13 Austria | 6 | Germany |
| C6 UK | 6.3% | 4.7% | -1.6% | C6 UK | 3 | Spain |
| C14 Italy | 4.8% | 20.3% | 15.5% | C14 Italy | 3 | France |
| C11 Switzerland | 4.7% | 6.0% | 1.3% | C11 Switzerland | - | Switzerland |
| C21 Turkey | 4.0% | 3.3% | -0.7% | C21 Turkey | 9 | England |
| C10 Slovenia | 3.3% | 1.1% | -2.2% | | | |
| C12 Belgium | 2.8% | 4.4% | 1.6% | | | |
| C1 France | 2.5% | 7.1% | 4.6% | | | |
| C18 Poland | 1.5% | 3.3% | 1.8% | | | |
| C23 Sweden | 1.4% | 1.82% | 0.4% | | | |
| C4 Denmark | 1.2% | 1.77% | 0.6% | | | |
| C20 Greece | 0.6% | 2.68% | 2.1% | | | |

Table 5. Value distribution of rating questions

| | | Value distribution in lickert scale | | | | |
|----------|---------------------------|-------------------------------------|-------|-------|-------|-----------|
| | | R0 | R1 | R2 | R3 | Mean |
| Question | Q1 'I know the piece' | 33.0% | 14.0% | 12.0% | 33.0% | 1.49 ±1.3 |
| | Q2 'I like the piece' | 15.0% | 25.0% | 25.0% | 28.0% | 1.71 ±1.1 |
| | Q3 'I enjoy dancing it' | 21.0% | 22.0% | 21.0% | 29.0% | 1.63 ±1.1 |
| | Q4 'Piece is challenging' | 35.0% | 25.0% | 16.0% | 14.0% | 1.10 ±1.1 |
| | Q5 'Piece is danceable' | 13.0% | 17.0% | 23.0% | 40.0% | 1.96 ±1.1 |

We compared country information obtained from the survey to the geographical distribution of performances as collected in the network analysis study (compare subsection 3.1). We found discrepancies such as the fact that Italy is under-represented in the regions named by survey participants. A large number of *tango argentino* events takes place in Italy, but a small amount of people stated that their current tango region is in Italy. We also computed the difference in ranking between the countries found in the survey and in the network analysis study. Results were roughly comparable (compare Table 4).

The 6589 received ratings answered one or more of the variables Q_1 , Q_2 , Q_3 , Q_4 and Q_5 for a specific piece of music (we note that in over 90% of all cases we received answers for all five variables). Table 5 displays the overall distribution of answers. We observe that Q_1 shows a U-shaped distribution, indicating that participants know pieces either very well or not at all. We also observe that Q_2 and Q_3 are both almost equally distributed. Q_4 shows an L-shaped distribution in which most pieces are not perceived as challenging, and Q_5 shows a J-shaped distribution in which most pieces are considered danceable.

Pearson's correlation coefficients for the variables Q_1 , Q_2 , Q_3 , Q_4 and Q_5 , are shown in Table 6. We found strong evidence for a relation between knowing and liking a piece and finding it danceable. Little evidence

Table 6. Correlation of rating question results

| Question | Pearsons correlation of ratings | | | | | Correlation Grade | |
|---------------------------|---------------------------------|--------|--------|--------|--------|-------------------|----------|
| | Q1 | Q2 | Q3 | Q4 | Q5 | | |
| Q1 'I know the piece' | +1.000 | | | | | 1.0 - 0.5 | Strong |
| Q2 'I like the piece' | +0.570 | +1.000 | | | | 0.5 - 0.3 | Moderate |
| Q3 'I enjoy dancing it' | +0.530 | +0.810 | +1.000 | | | 0.3 - 0.1 | Weak |
| Q4 'Piece is challenging' | -0.130 | -0.020 | -0.100 | +1.000 | | 0.1 - 0.0 | None |
| Q5 'Piece is danceable' | +0.460 | +0.590 | +0.740 | -0.230 | +1.000 | | |

was found for a relation between the challenging nature of a piece and its perceived danceability. Correlations included:

- Q1/Q2 (**Strong**) Participants tend to like pieces they know
- Q1/Q3 (**Strong**) Participants tend to enjoy dancing to pieces they know
- Q2/Q3 (**Strong**) Participants tend to enjoy dancing to pieces they like
- Q2/Q5 (**Strong**) Participants tend to consider pieces they like more danceable
- Q3/Q5 (**Strong**) Participants tend to consider pieces they enjoy dancing more danceable
- Q1/Q5 (**Moderate**) Participants tend to find known pieces more danceable
- Q4/Q5 (**Weak Negative**) Participants tend to find challenging pieces less danceable

We computed average normalized values of the rating variables $Q1$ to $Q5$ for all musical pieces used in the survey. We have also computed a rough *Danceability Score* $S1$ as a normalized linear combination of variables $Q2$, $Q3$ and $Q5$, and used this score to rank the pieces (compare [52]).

When we started to collect information about “danceable” tango tunes in online communities, several key members immediately voiced their suspicion that we were to create a list of top tangos to play. The pieces a tango DJ chooses to play during an evening are influenced by many factors, including location, mood, organizer preferences, personal preferences, fashions and many more. The ranking of pieces by danceability that resulted from our study can therefore provide no more than a rough guide to the individual perception of danceability. It is most definitely not a recommendation on which pieces to play in which order at a *milonga*.

We observe that the vast majority of Golden Age Tango pieces are at the top of the ranking and the vast majority of contemporary and alternative pieces are at the bottom of the ranking. For instance, the best ranking contemporary piece of music is placed 26th, and the best ranking alternative piece of music is ranked 33rd.

We aggregated several of the variables related to participants into four indicators:

- I1 – Scene Integration** Denotes the amount to which a participant is integrated into regional and international scene activity. We compute it as a normalized linear combination of $U4$ *User dance frequency*, $U7$ *User is tango Dj*, $D5$ *User dances Marathons* and $D6$ *User dances Encuentros*. Restricted marathons and *encuentros* more often accept the participation of well-integrated scene members. Also, well-integrated scene members often serve their local communities as DJs.
- I2 – Professionalism** Denotes how far the activities of a participant have advanced into the professional or commercial domain. We compute it as a normalized linear combination of $U5$ *User is musician*, $U6$ *User is dance teacher* and $U7$ *User is tango Dj*. $U5$ and $U6$ both include professionalism as their maximum extent.
- I3 – Music Affinity** Denotes the degree to which a participant is involved with music in and beyond the *tango argentino* domain. We compute it as a normalized linear combination of $U5$ *User is musician*, $U7$ *User is tango Dj* and $U8$ *User musical experience*. $U8$ measures musical experience as a duration.

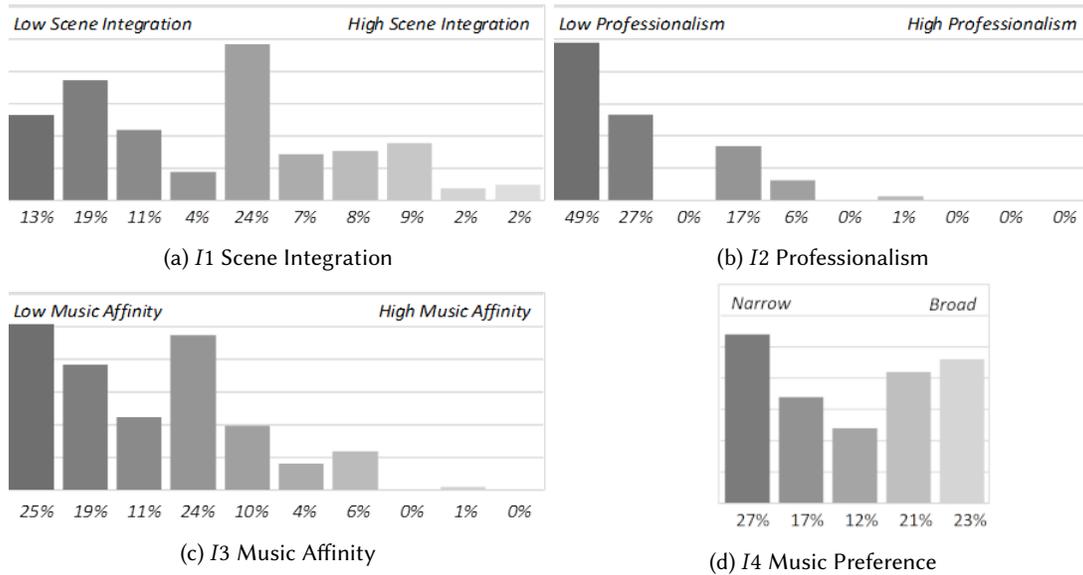


Fig. 5. Histograms of the four computed indicators. Missing answers have been omitted (< 10%).

I4 – Music Preference Denotes how broad or narrow the musical taste of a participant is. We compute it as a normalized linear combination of *M1 User likes Golden Age Tango*, *M2 User likes Contemporary Tango*, *M3 User likes Live Tango*, *M4 User likes Electro Tango* and *M5 User likes Alternative Tango*.

The value histograms¹² of the four indicators are shown in Figure 5. We observe that *I1* displays a bimodal distribution with a strong peak at low values and another strong peak at medium values: Most participants were either entry-level dancers consuming, but not contributing, to the *tango argentino* scene, or medium-level contributors and consumers. We also observe that *I2* and *I3* display L-shaped distributions, and that *I4* shows a U-shaped distribution in which most participants have an extreme tango musical preference, either very narrow or very broad. Pearson’s correlation coefficients for the indicators *I1*, *I2*, *I3* and *I4*, are shown in Table 7. We found strong evidence for a relation between professionalism and musical affinity, and weak evidence for an inverse relation between range of musical preferences and professionalism, integration and musical affinity. Correlations included:

I1/I3 (Strong) Participants with a professional orientation tend to exhibit more musical affinity

I1/I2 (Moderate) Participants with a professional orientation tend to be more integrated

Note that all indicators *I1*, *I2* and *I3* show a weak negative correlation to *I4*: The more integrated or professional a *tango argentino* scene member, and the more musical affine, the narrower the tango musical preferences.

Another indicator *I5 – Tango Dance Experience* captures all aspects of dance experience and expresses involvement in dance, but not professionalism or musical affinity. This indicator is comprised of several scoring factors, including *U3 User Dance Experience* (2 points), *U4 User Dance Frequency* (2 points), *D2 User dances local Milongas* (1 point), *D3 User dances international Milongas* (2 points), *D4 User dances Festivals* (2 points), *D5 User dances Marathons* (3 points) and *D6 User dances Encuentros* (3 Points), for a total of 15 points. We used this indicator in further analysis in normalized form. Based on this indicator, we computed the dependencies between the

¹²Missing answers were omitted, which accounted for less than 10% in all cases.

Table 7. Correlation of rating question results

| | | Pearsons correlation of indicators | | | | Correlation Grade | |
|------------|----------------------|------------------------------------|--------|--------|--------|-------------------|----------|
| | | I1 | I2 | I3 | I4 | | |
| Indicators | I1 Professionalism | +1.000 | | | | 1.0 - 0.5 | Strong |
| | I2 Scene Integration | +0.395 | +1.000 | | | 0.5 - 0.3 | Moderate |
| | I3 Music Affinity | +0.612 | +0.154 | +1.000 | | 0.3 - 0.1 | Weak |
| | I4 Preference Range | -0.159 | -0.221 | -0.133 | +1.000 | 0.1 - 0.0 | None |

S1 – Danceability Score participants assigned to pieces of certain styles and the *I5 – Tango Dance Experience* indicator (compare Figure 6). We observe that participants with more *tango argentino* dance experience tend to rank Golden Age Tango pieces higher than Contemporary or Alternative pieces.

3.2.3 Interpretation. We have just started in-depth analysis and interpretation of collected data and want to present some initial findings below, but expect our understanding of the data and the underlying phenomena to continue to grow. Other experts are encouraged to further analyze the data set, which we have made available online for research purposes.

We consider the amount of data collected (6,589 ratings from 182 participants for 80 pieces of music) sufficient for detailed quantitative analysis. Taking into account scene experts' insights, the age and gender distribution of the sample is representative. Compared with our study of *tango argentino* performances in Europe, the regional sample distribution is sufficient, if not representative. We keep the over-representation of German speaking countries and the under-representation of Italy and Spain in mind when drawing conclusions. Based on validation by scene experts, we consider the distribution of various *tango argentino*-related parameters, as expressed through indicators *I1* to *I4*, as roughly representative of a typical sample of the European *tango argentino* scene.

From the correlations computed for variables *Q1* to *Q5*, we conclude that there is a general tendency in the European *tango argentino* scene to enjoy dancing to well-known music. We also cautiously conclude that there is a tendency to stay in the personal comfort zone when dancing and to consider challenging pieces less danceable.

From the ranking of pieces obtained through score *S1* (compare [52]), we conclude that the current European *tango argentino* scene is very much in favour of *época de oro tango argentino* pieces, and this conclusion perfectly matches the opinion of scene experts, and our own observations. We also conclude from the detailed values of variables *Q1* and *Q2* that many pieces of contemporary *tango argentino* are little known in the European *tango argentino* scene, but are, or would be well liked, and be considered danceable. If we remove the correlation between knowing and liking a piece from our indicators (by inversely weighing all influence factors by knowledge of the piece), several contemporary pieces appear within the top 20 danceable pieces.

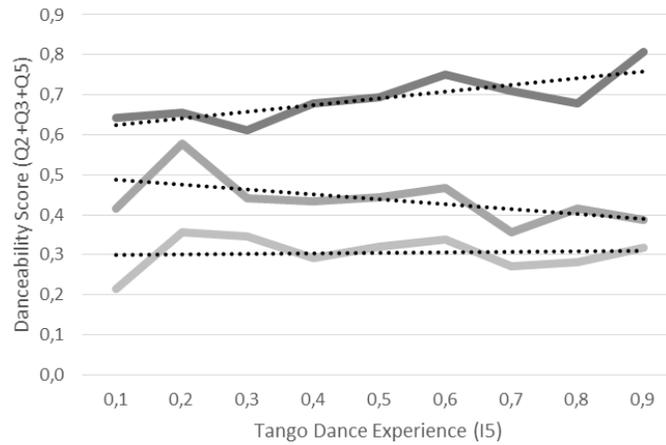
We cautiously interpret the bimodal distribution of *I1* and, to a lesser degree, *I2* and *I3*, as an indication of a European *tango argentino* scene structured in an actor network, with a large number of mainly regional consumers and a smaller number of networked contributors acting on a European level and serving as gatekeepers.

We interpret the U-shaped distribution of *I4* as an indicator of an individual radicalization of musical preferences, which scene experts also have pointed out. There seem to be two distinct groups in the European *tango argentino* scene: One group explicitly limits musical preference to *época de oro tango argentino* music, and the other explicitly broadens musical preference to contemporary and alternative music.

Finally, we interpret the relation between *S1 – Danceability Score* and *I5 – Tango Dance Experience* as directly supporting one of our core hypotheses. Figure 6 clearly shows that a high level of *tango argentino* dance experience, whether measured in years of dance practice or diversity of dance activities attended, corresponds to a more positive rating of Golden Age Tango music and to a less positive rating of Contemporary and Non-Tango music.

(a) Tango Dance Experience per musical style

| | | I5 Tango Dance Experience | | | | | | | | | |
|------------|---------------|---------------------------|------|------|------|------|------|------|------|------|------|
| | | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| Golden Age | Di Sarli | 0.52 | 0.68 | 0.74 | 0.55 | 0.70 | 0.79 | 0.80 | 0.80 | 0.68 | 0.77 |
| | Rodríguez | 0.66 | 0.78 | 0.68 | 0.63 | 0.69 | 0.72 | 0.81 | 0.73 | 0.65 | 0.87 |
| | D'Arienzo | 0.64 | 0.61 | 0.66 | 0.72 | 0.71 | 0.76 | 0.80 | 0.74 | 0.72 | 0.88 |
| | Biagi | 0.55 | 0.39 | 0.57 | 0.56 | 0.67 | 0.74 | 0.78 | 0.73 | 0.65 | 0.85 |
| | Pugliese | 0.64 | 0.67 | 0.67 | 0.58 | 0.71 | 0.62 | 0.68 | 0.65 | 0.69 | 0.76 |
| | Canaro | 0.57 | 0.60 | 0.54 | 0.50 | 0.60 | 0.61 | 0.67 | 0.68 | 0.66 | 0.65 |
| | Troilo | 0.63 | 0.70 | 0.71 | 0.69 | 0.73 | 0.62 | 0.76 | 0.66 | 0.74 | 0.89 |
| | Tanturi | 0.53 | 0.72 | 0.66 | 0.66 | 0.61 | 0.66 | 0.71 | 0.69 | 0.63 | 0.80 |
| Contemp. | Andariega | 0.31 | 0.42 | 0.56 | 0.39 | 0.44 | 0.51 | 0.45 | 0.36 | 0.41 | 0.38 |
| | Almagro | 0.36 | 0.32 | 0.56 | 0.39 | 0.36 | 0.37 | 0.48 | 0.33 | 0.38 | 0.37 |
| | La Vidú | 0.38 | 0.37 | 0.50 | 0.38 | 0.35 | 0.32 | 0.38 | 0.27 | 0.31 | 0.33 |
| | Sabor a Tango | 0.52 | 0.55 | 0.69 | 0.60 | 0.59 | 0.57 | 0.56 | 0.47 | 0.57 | 0.47 |
| Non-Tango | 0.24 | 0.22 | 0.36 | 0.35 | 0.29 | 0.32 | 0.34 | 0.27 | 0.28 | 0.32 | |



(b) I3 Dependency of Danceability and Dance Experience.
 Top (dark): Golden Age Tango Music, Middle (medium): Contemporary
 Tango Music, Bottom (light): Non-Tango Music

Fig. 6. Dependency between S1 Danceability Score and I5 Tango Dance Experience.

We conclude that musical preference in *tango argentino* dancing is at least in part a socio-normative phenomenon. It seems that prolonged exposure to the traditional norm of the *tango argentino* scene causes perceived danceability to narrow towards this norm.

3.3 Motion Capture Based Movement Analysis

The study focuses on the currently most prominent and commonly practiced tango dance style. It is characterized by a close embrace and close connection of the dance partners from the waist upwards, and flexible and elaborate footwork made possible mainly by horizontal dissociation movements in both dancers' waists. The embrace is occasionally opened for short intervals of more elaborate movements (e.g. back *sacadas*, *giros*)¹³. We analyzed what actually defines tango movements in order to find possibilities as well as boundaries in its repertoire.

Tango argentino is a highly improvised dance, which is mainly based on striding and turning techniques rather than particular step sequences. It would therefore be of no use to examine step patterns or advanced movement combinations in tango. On the contrary, to explain movements that are particular for tango, it is the most basic elements that need to be looked at: posture, striding and turning. We consider it impractical to use elaborate, written methods of movement analysis like Labanotation or Laban Movement Analysis [25, 31, 32] for this case, since it is more than likely that the essential features of tango striding and turning lie within the dynamics of individual body segments, such as acceleration, body tension, dissociation, micromovements, or relative broadness of isolated motion structures. All of these particular aspects of movement, relevant to time, are difficult to capture with Laban. In order to generate quantifiable data out of the tango movement and sound repertoire, we engage with computer aided routines of capturing and analysis.

Motion capture technology offers options for this particular research question (e.g. [17, 27, 37]) by facilitating the required motion studies. First, explicit synchronization with external auditive information (such as music) can easily be integrated into existing systems or synchronized in post processing procedures. This allows for the investigation of sound-movement interrelational parameters on the level of microseconds. Second, precise movement data can be captured, and if further developed into a user friendly output, can expand or even supplant "thick descriptions" [23]. This also applies to sound data, whose analysis consequently demands a finer level of granularity for optimal compatibility with the captured movement data. In order to achieve the required precision, the field of Music Information Retrieval (MIR) (e.g. [15]) offers valuable methods of individually adaptable procedures for low- and high-level feature extraction.

3.3.1 Requirements. Motion capture technology and Information Retrieval are steadily finding their way into the humanities, especially in research questions related to sound and movement, or in particular, music and dance. They may focus exclusively on one of these aspects, highlighting either musical parameters (e.g. [13, 48]) or only motional structures (e.g. [12, 21, 36]). The complex interrelation of these two factors however has now opened up as a promising field of research (e.g. [10, 17, 37, 40]). Leman's theory of embodied music cognition [34] laid the foundation for these approaches, tying sound and movement intrinsically together. This cognitive relationship is also significant in the sensory motor theory of [53, 54], who were able to develop a working heuristic model of their idea, effectively proving the strong interconnection of motion and time perception.

Research specifically examining tango dance is provided by [29] and [3]. The former concentrate on extensive motion analysis in dynamic coordination of two dance partners, while the latter developed advanced position estimation of multiple bodies in an inertial motion capture system in order to determine salient features of the *tango argentino* dance style. Yet, none of them have incorporated sound analysis into their research.

[38] draw attention to a problem in the context of musical meter and rhythm theory, which also applies to many empirical studies beyond music. Their main point is that the research within different musical cultures cannot be simplified with a general approach, since it actually adheres to one particular culture, often the researcher's own. This means that analyses of human movement have to be informed by knowledge about the specific cultural domain in which the movement is embedded. This issue is well known and incorporated in the fields of ethnochoreology and ethnomusicology. In consequence, experiments have to be modified in their design. The

¹³See for example [45] for an explanation of movement terms.

“quest for numerical evidence”, as Naveda puts it [38], and its strongly restricted experimental setups can suppress many individual facets that may contribute to the movement in question. The aim should be the opposite: less control over the design consequently leads to more analytical complexity in favor of more external validity (see [7]). Whereas Naveda focuses on free, unconstrained body movement, these thoughts can be applied to concrete movement systems. For the current study, this means that the experiment is designed with insider knowledge about the *tango argentino* style, leading to a focus on a particular aspect of the music-movement connection, while keeping the laboratory situation as close as possible to an actual dance context. The combination of restricted movement tasks and free dancing allows the researcher to cover a wide range of possible variables describing the relationship of music and movement in *tango argentino*.

3.3.2 Experiment Design. Qualitative analyses was carried out by working with three couples of professional tango dancers¹⁴. They were selected by their popularity and influence in the European tango scene, observable by their frequent invitations to European festivals and prolonged tours across the continent. Dancers were asked for four kinds of movement tasks: tapping, regular walking, tango walking, and dancing. Foot tapping and walking was performed alone while the dancing task was performed in a couple. For this, four different auditive stimuli were used, three of which were supplied by the project researchers, representing

- (1) the tango recording that was rated most danceable according to the results as seen on [52]
- (2) a tango composition by Robert Schmidt particularly produced for this project, based on parameters that were found to be ideally contributing to danceability
- (3) a tango piece chosen by each professional tango dance couple to which they feel most comfortable dancing to
- (4) a computer generated click track with isochronous beats as a control entity for beat referencing

All trials were captured by an infrared-based optical motion capture system alongside a recording of the music for later synchronization. Further processing and analysis of the captured data is executed in MATLAB on the basis of two toolboxes: MoCap [11] and MIR [33]. The migration of data to external software is expected to allow for optimal compatibility of all results and easier synchronization of the two separate formats.

The main attention in the examination of the sound and movement data deals with the corporeal referencing of the auditorially perceived beat of the lower limbs, as tango synchronization to music is primarily realized on the level of the feet. This factum can easily be observed in the way moving ‘to’ the music in tango is taught, for example by [1] who describes a method of instructing dancers “without musical education” by concentrating on the steps. Possible criteria to be observed then are the temporal placement of salient pivotal points within the kinematic features of foot and leg movement such as the contact of foot segments with the ground or the periodicity of leg acceleration patterns within the gait cycle.

In order to analyze the specific relationship between a beat and its corporeal implementation, several aspects have to be considered. In order to reference a beat, its location in the music has to be defined first. As a subjectively perceived entity, any perceived periodic event within an auditory stream could be defined a “beat”, though most musical systems rely on beat as a subdivision of an underlying pulse that defines temporal aspects of the music. Leman [34] delivers an interpretation suitable for embodied cognition and computing: “Spontaneous movements may be closely related to predictions of local bursts of energy in the musical audio stream, in particular to the beat and the rhythm patterns”. Continuing this thought, in structured movements, such as (tango) dance, the prediction is actually a necessary part and reference to rhythm is intended. As this research takes place with a musical form that relates to Western music theory, metrical concepts can clearly be defined in notation. This means the referential time points within tango music are the four beats given in a $\frac{4}{4}$ measure in which *tango*

¹⁴Couple 1: Yanina Quiñones and Neri Piliu, Couple 2: Homer and Cristina Ladas, Couple 3: Maja Petrović and Marko Miljević, names published with permission of dancers.

argentino music pieces are usually notated. These beats can be well perceived by performers due to the frequency of their occurrence and their instrumentation [41]. Regular, low frequency pulses as played by the double bass or the piano can help in this synchronization task [16]. Having defined beat locations within the macro structure leaves open the important question of how to define those locations for analysis on a far finer level of time. Earlier approaches do not go into detail on how they defined absolute temporal location of the beat, but rather use manual annotation. Since several studies show the existence of a negative asynchrony in synchronization tasks (see [4] for a synopsis) this approach must be further refined to account for the subtleties in *tango argentino* dance. Different methods of Music Information Retrieval are therefore applied to extract features that relate to time perception in tango music, such as note onsets, energy peaks or temporal evolution of low spectral components.

3.3.3 Case Study. To demonstrate the described approach, we present preliminary results of investigating the relation of musical beats with dancers' gait events. Since looking at absolute beat points in the music is not feasible on the level of detail used here, we rather adopt segments relating to these points, as used by [38]. Naming these segments "metrical", however, implies the use of a meter, which attaches an inherent order of significance to different beats in a sequence. We therefore specify beat segments with no differentiation between distinct instants. They are defined as a time window around an approximate absolute beat time instants t_{Bi} with its boundaries t_{Wi1}, t_{Wi2} set at the middle between two consecutive beats: $t_{Wi1} = \frac{t_{Bi} - t_{Bi-1}}{2}$ and $t_{Wi2} = \frac{t_{Bi+1} - t_{Bi}}{2}$. The beat time instant is determined by a beat tracking method implemented in SonicVisualiser (<https://sonicvisualiser.org/>) which combines¹⁵ approaches of [14], [18] and [49]. The complex domain algorithm yields the most centered results in comparison to other settings and is therefore used.

After defining beat segments, gait events are defined by detecting heel strike instants (HSI) in the motion data. As there is no force data available, the kinematic approach described in [5] is applied. It is especially suitable for tango walking, as it only considers the distance of heel markers, placing the HSI on relative maxima of the distance curves. This allows for steps in different directions (straight, lateral, diagonal, backwards), without constraining the dancers in their walking task. All detected HSI then are assigned their two closest segment boundaries, using a k -nearest neighbor search ($k = 2$).

The relation of the HSI to the beat segments is defined as the ratio of the distances to its first, d_1 , and second segment boundary, d_2 : $p_{rel} = \frac{d_1}{d_2}$. The result is a relative position of a HSI within a beat segment in the range of $[0, 1]$, with 1.00 meaning very close to the beat, and approaching 0.00 meaning furthest away from a detected beat. This yields a distribution of the defined gait events within beat segments.

A simple visualization of the distribution of relative gait event positions already gives ideas about the way the beat is implemented in tango walking. The box plots show a comparison of two different movement tasks of a single subject, where one is within the tango movement repertoire (tango walking), and the other outside (heel tapping, seated). The exact values of the plots are not relevant but rather their shape, indicating how far spread the HSI are within the beat segments. Comparing the different movement tasks, it can clearly be seen that tango walking to tango music allows for a broader variability in following the beat with the feet (Tango Walking Personal: $\mu = 0.69$ $\sigma = 0.26$, Composed: $\mu = 0.57$ $\sigma = 0.29$, Click: $\mu = 0.91$ $\sigma = 0.01$; Heel Tapping All: $\mu \geq 0.95$ $\sigma < 0.0002$). The results for the tapping task show that the subject is able to keep a steady beat, which indicates that the fluctuations in tango walking are not due to an incapacity of the dancer, but rather part of the movement itself. Additionally, tango walking on a simple external pulse (without any other musical aspects) reduces the variability, resulting in a plain synchronization task.

These findings lead to important assumptions about the way of synchronizing walking in *tango argentino* to the musical beat. The exact matching of the steps to the beat does not seem to be a crucial part of tango walking.

¹⁵For a detailed explanation of the algorithm, see <https://vamp-plugins.org/plugin-doc/qm-vamp-plugins.html#qm-tempotracker>.

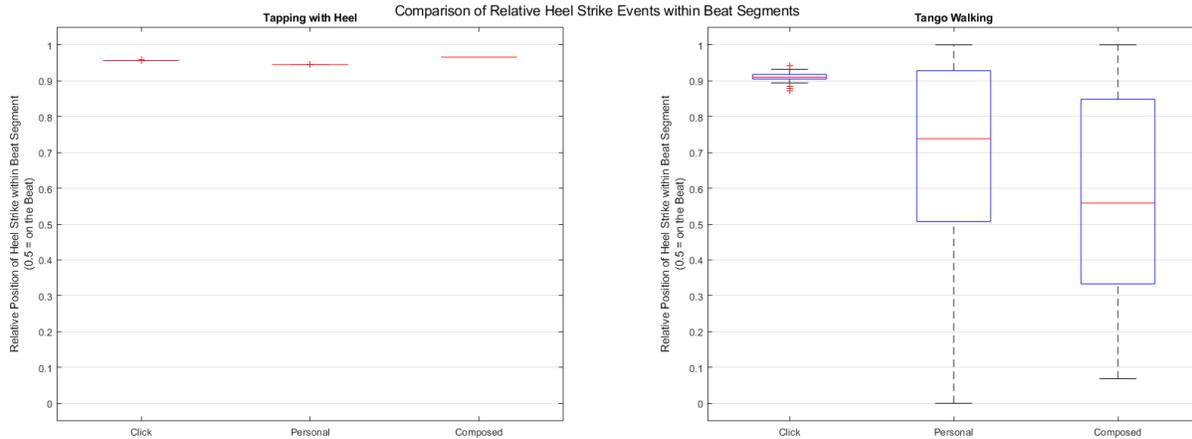


Fig. 7. Box plots of the relative position of heel strike instants within beat segments. Two tasks for one subject are compared: heel tapping (seated) vs. tango walking. The groups are three different stimuli: the click track (Click), the self-chosen piece (Personal), and the newly composed piece (Composed). The closer a value is to 1.00, the closer the heel strike is to the beat. The exact values are not of importance here, but rather their position and range in regard to the movement task.

This might connect to the idea that the body should move smoothly in space while dancing. Not being tied to a perfect synchronization of the feet can facilitate this by avoiding jerky motion to reach beat points. This also supports an idea coming from our experience as tango dancers, where a tighter synchronization actually happens by shifting the body’s center of gravity periodically.

The given example demonstrated the idea of analyzing the relation of music and dance, resulting in important insights by simple means of movement and music analysis. The used methods are well established within their respective fields and open up a variety of possibilities in combining the different approaches. Further studies will elaborate on the assumptions raised in this investigation and other issues, such as differences in movement ‘with music’ and ‘without music’ or questions regarding the style of individual dancers. Finding these idiosyncrasies can help to understand where boundaries in movement are, and narrow down variants to approach a hypothetical ‘norm in tango movement’.

4 CONCLUSION AND OUTLOOK

This paper introduced the project “Tango-Danceability of Music in European Perspective”. We presented how the project brings together different research traditions into a truly transdisciplinary research concept and design. Theories and hypotheses developed from experiences as insiders in the international *tango argentino* culture – from within the academic fields of ethnochoreology and ethnomusicology – are supplemented by digital and quantitative methods, first, to gather more precise data, and second, to gain deeper insights than could have been attained from either of the involved fields of research separately.

For one of our examples, we included data and analysis from the area of “network analysis”. Within this area, so far, the following hypotheses have been substantiated:

- (1) Statistical analysis of survey results has demonstrated a strong correlation between subjectively knowing and liking a musical recording and considering that piece danceable in a general sense. The individual concept of danceability therefore appears to be a generalization of subjective experiences.

- (2) The international *tango argentino* social network is hierarchically organized and is strongly influenced by gatekeepers in central professional or organizational positions (see subsection 3.1, Figure 2 and Table 7).
- (3) Network analysis has shown that a surprisingly small number of gatekeepers (in this case, internationally performing tango DJs), selects the tango music a large number of dancers gets to know, and perceives as the norm.
- (4) Gatekeepers do not choose tango pieces randomly, but based on personal experience, knowledge and exchange with other experts. In order to identify forces behind this selection process we currently conduct further expert interviews which will shed light on this phenomenon.
- (5) Observations and personal experiences in the scene as well as collected data show, that a significant majority of tango dancers, independent of all examined variables, currently prefer tango music from the *época de oro*. The more integrated a tango dancer, and the longer the dancer is part of the scene, the more likely it is that he/she will rank pieces from the Golden Age more danceable and Contemporary and Alternative Tango pieces less danceable (see Figure 6).

This suggests that gatekeeping and social network phenomena are the main force behind the standardization (and possibly also further development) of music and dance trends in the international *tango argentino* scene. The results so far indicate that the initial broad musical preferences of tango dancers are narrowed down, according to a prevalent scene norm. This norm is influenced by the preferences of the gatekeepers.

We conclude that transdisciplinary research design based on expert knowledge in all related fields is a most promising approach. Preliminary results presented in this paper are unprecedented, and confirm the validity and advantages such an approach has over conventional studies in only one academic discipline.

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